Province of Prince Edward Island

Department of Energy and Forestry
Energy and Minerals Branch

Geology of Prince Edward Island

by
H. W. van de Poll

Report 83-1

Charlottetown, P.E.I.
1983

ISBN-0-ISBN-0-9690363-1-0

Poll, H.W. van de, 1932-
Geology of Prince Edward Island, 1983
66 p. + viii
62 references

Publisher: Queen's Printer, Charlottetown, P.E.I., Canada

Geology; Lithostratigraphy; Sedimentology; Redbeds; Structural Geology; Economic Geology; Uranium; Gravel Resources; Eastern Canada; Prince Edward Island.

Library of Congress class:
QE192.P6 1983

Dewey Decimal class:
557.17P6 1983

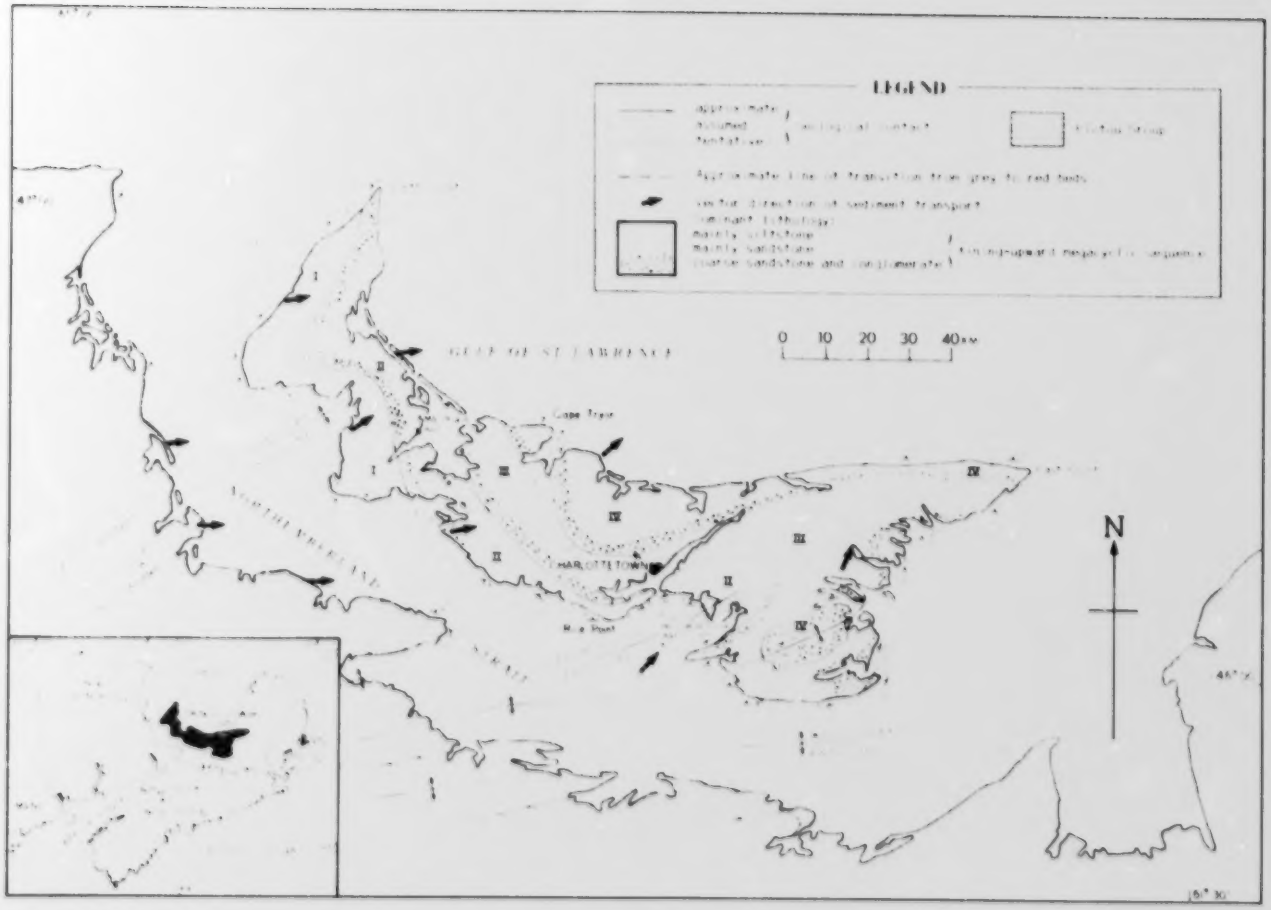
c 1983 Province of Prince Edward Island

H.W. van de Poll,
Department of Geology,
University of New Brunswick,
Fredericton, N.B. E3B 5A3.

Charlottetown : The Queen's Printer

Production and Design : Herrington Associates

The photograph on the front cover is of Prince Edward Island redbeds in cliffs at the Lord Selkirk Provincial Park, Queens County, 25 km southeast of Charlottetown


LEGEND
0 10 20 30 40 km
N

ABSTRACT

Study of the surface and subsurface geology of the Prince Edward Island redbeds has resulted in an increased knowledge of their lithostratigraphy and structure. They have been provisionally included in the Pictou Group (Upper Pennsylvanian) of Nova Scotia and New Brunswick on the basis of their apparent lithogenetic continuity and conformable relationships; the correlation is consistent with earlier evidence from fossil plants, spores and vertebrates. The redbed sequence is Stephanian to Early Permian in age.

Subdivision of the redbed sequence is based on the mapping of four major lithostratigraphic subdivisions, informally designated Megacyclic Sequences I to IV (MS.I - MS.IV). Smaller stratigraphic units are present in some areas; these have been designated subcyclic sequences (SS.IA, SS.IIIA). Each consists of an upward-fining sequence grading from relatively coarse conglomerate at the base, through coarse to fine sandstone alternating with siltstone, to very fine sandstone and siltstone at the top. Each unit is 300-400 m thick, made up of repeated fluvial cycles up to 20 m thick.

Megacyclic Sequence I is Upper Pennsylvanian (Stephanian) in age, containing numerous plant-fossil impressions. Palynological evidence from drill samples supports this age interpretation. Megacyclic Sequence II is probably Early Permian, based on spore data. Vertebrate bone fragments have been reported from several Island localities, and trace fossils resembling worm tubes are widely present; on the basis of these remains, Megacyclic Sequences III and IV appear to be Early Permian (Artinskian) in age.

The redbed sequence was deposited by fluvial action in a semi-arid flood-plain environment, with sediment being derived mainly from the southwest; the mean transport direction indicated by crossbedding is 047°.

Structural deformation is minor but a gentle northeastward tilting and folding along axes oriented mainly northeast-southwest are present. These can be attributed to uplift of a buried basement horst (the Kingston Uplift) which extends from New Brunswick to the Island, and from salt diapirism at depth.

The subsurface geology of the Island consists of an igneous and metamorphic basement, overlain by Mississippian conglomerate, arkosic sandstone, shale, mafic volcanic rocks and evaporites. Above a major disconformity, Pennsylvanian strata are present which correlate with the coal-bearing rocks of New Brunswick and Nova Scotia.

Uranium mineralization has been detected locally in the redbeds, showing analytical values of up to 10 times backgound. The mineral occurrences are of two main types: (a) grey reduction spheroids with dark cores in very fine grained sandy siltstone, and (b) mineralized greyish-green reduction zones at the base of channel units where they overlie red siltstone.

Gravel deposits formed of weathered conglomerate strata occur at a number of localities, and further deposits may be present along the line of the outcrops of conglomeratic bases of MS.II, MS.III and MS.IV.

FOREWORD

This report is the first comprehensive account of the Geology of Prince Edward Island to have been published by the provincial government. As such, it will remain a standard reference work for many years to come. While the present study is something of a landmark, the work of researching and reporting on the mineral potential of the province is a continuing enterprise. The provision of new geological information as it comes to light is a major factor in maintaining an interest in mineral exploration in any province, and it is an essential element in this government's exercise of its stewardship over its mineral resources. The "Geology of Prince Edward Island",then, should not be viewed as an isolated contribution, but as the start of an ongoing government commitment to the development of P.E.I's mineral resources.

Hon. Frederick L. Driscoll
Minister of Energy and Forestry

September 1983

CONTENTS

	page
ABSTRACT	iii
ACKNOWLEDGMENTS	viii
INTRODUCTION	1
PHYSIOGRAPHY	2
GEOLOGY	2
AGE OF THE STRATA	2
ROCK TYPES	4
LITHOLOGICAL DESCRIPTIONS	4
Silt and Claystone	4
Limestone	4
Sandstone	5
Intraformational Mud-pellet Conglomerate and Chaotic Breccia	5
Intraformational mud-pellet conglomerate	6
Chaotic breccia	6
Pebble and Cobble Conglomerate	6
Tholeiitic Diabase	8
LITHOSTRATIGRAPHY	9
Megacyclic Sequence I (MS.I)	11
Subcyclic Sequence IA (SS.IA)	16
Megacyclic Sequence II (MS.II)	16
Megacyclic Sequence III (MS.III)	18
Subcyclic Sequence IIIA (SS.IIIA)	19
Megacyclic Sequence IV (MS.IV)	19
SEDIMENTOLOGY	21
SEDIMENTARY CYCLICITY	21
SEDIMENTARY STRUCTURES AND SEDIMENT DISPERSAL	23
Primary Directional Sedimentary Structures	24
Cross-bedding	24
Parting lineation	26
Ripple marks	27
Secondary Sedimentary Structures	27
SUBSURFACE GEOLOGY	34
STRUCTURAL GEOLOGY	36
Structure	36
Western part of the Island	36
Lowland areas centred on Egmont Bay	38
Lowland areas of central Prince County centred on Malpeque and Bedeque Bays	38
South-central areas of the Island (eastern Prince and western Queens Counties)	38

Hillsborough Bay area 38
North-central part of the Island 39
Northeastern part of the Island 39
Southeastern part of the Island 39
Faults 40
Joints 41

ECONOMIC GEOLOGY 42
Uranium 42
Gravel 45

SUMMARY AND CONCLUSIONS 46

BIBLIOGRAPHY 49

APPENDIX

Appendix I Summaries of Borehole Logs of Wells in Prince Edward Island 55

TABLE

Table 1 Lithostratigraphic units present in Prince Edward Island 3

MAPS

Map 1 Geological Map of Prince Edward Island *in pocket*

Map 2 Scintillometer Anomaly Map of Prince Edward Island *in pocket*

FIGURES

Figure 1 Carboniferous-Lower Permian geology of Prince Edward Island and neighbouring coastal areas of New Brunswick and Nova Scotia, showing lithology and sediment transport vectors of the Prince Edward Island redbeds. *Frontispiece*

Figure 2 Carboniferous conglomerate compositions from southern New Brunswick and Prince Edward Island (Assemblages A, B and C), showing limits of one standard deviation 7

Figure 3 Imprint of *Pecopteris arborescens* in red sandstone, Subcyclic Sequence IA, 10 km southwest of North Point 13

Figure 4 Imprint of *Walchia gracilis* in red silty sandstone, Subcyclic Sequence IA, 10 km southwest of North point 14

Figure 5 Imprint of *Walchia robusta* in red silty sandstone, Subcyclic Sequence IA, 10 km southwest of North Point 15

Figure 6 Basal contact of red sandstone, mud-pellet and small-pebble conglomerate of Subcyclic Sequence IA with underlying red siltstone and very fine sandstone of Megacyclic Sequence I, west coast of Prince Edward Island 16

Figure 7 Quartz-quartzite-rhyolite conglomerate at the base of Megacyclic Sequence II at North Point 17

Figure 8 Relatively fine-grained upper part of Megacyclic Sequence II at Point Prim 17

Figure 9	Diagrammatic interpretation showing idealized vertical relationships and distribution of fluvial cycles with respect to the megacyclic subdivision of the Prince Edward Island redbeds	22
Figure 10	Sediment dispersal in Stephanian-Lower Permian strata of Prince Edward Island	25
Figure 11	Rose diagrams and vector orientation of cross-bedding and parting lineation, Prince Edward Island redbeds	26
Figure 12	Sediment interflow of red clay-siltstone in sandstone along horizontal to vertical pathways	28
Figure 13	Siltstone diapir in sandstone; Prince Edward Island redbeds, west of Wood Islands	29
Figure 14	Brecciform interval of clay-siltstone flakes, pods and lumps in sandstone; Prince Edward Island redbeds, East Point	29
Figure 15	Flute casts on the surface of a silt-injection cavity wall; Prince Edward Island redbeds, White Sands, east of Wood Islands	31
Figure 16	Partially exposed groove cast on the surface of a silt-injection cavity wall; Prince Edward Island redbeds at Point Prim	31
Figure 17	Relatively coarse *in situ* brecciation of sandstone that has partially destroyed original foreset bedding; Prince Edward Island redbeds, Campbellton	32
Figure 18	Relatively fine *in situ* brecciation of sandstone that has extensively destroyed foreset beds of crossbedding; Prince Edward Island redbeds, Campbellton	32
Figure 19	Clastic breccia pipe in Prince Edward Island redbeds, West Point	33
Figure 20	"Scalloped" intrastratal surface in Prince Edward Island redbeds, Point Prim	33
Figure 21	Bore-hole location map of Prince Edward Island	35
Figure 22	Synopsis of borehole intersections of Prince Edward Island	37
Figure 23	Rose diagram showing the orientation of joints in the western, southern and northeastern parts of Prince Edward Island	41
Figure 24	Mineralized reduction spheroid containing possible vanadium and uranium minerals in the dark core	44

ACKNOWLEDGEMENTS

The writer gratefully acknowledges the co-operation of Mr. N.G. Hall, former Director of Energy and Minerals, Department of Energy and Forestry, Province of Prince Edward Island, and H.E. Dunsmore of the Geological Survey of Canada, for initiating the study of Prince Edward Island redbeds and their economic potential, and for providing full access to Government files concerning the geology of the Province. Thanks are also due to Mr. J.R. DeGrace, present Director of Energy and Minerals, for completing the project by arranging publication of this final report. The project was supported by the Governments of Canada and Prince Edward Island under the P.E.I. Comprehensive Development Plan. The work was further aided by receipt of Energy Mines and Resources Canada Grant 72 4 82, which permitted final assessment of the stratigraphy prior to publication.

Thanks are also expressed for help from D.M., R.W.W. and Ch.D.S van de Poll and Mr. P. Weeks for assistance in the field work, including map preparation and scintillometer surveying and to Dr. D.J.C. Laming for critical assessment of the field evidence and the report. Secretarial assistance was provided by Ms. S. Townsend, Mrs. B.A. Hosking and Mrs. J. Plumer; and drafting by Mr. G. Johnson and Mrs. D. Jones. Professor W.M. Forbes of the University of Maine of Presque Isle, Maine, U.S.A., identified the follil plant imprints and Ms. O.D. Sandler of the same institution did the photography of the fossil flora included in this report.

GEOLOGY OF PRINCE EDWARD ISLAND

INTRODUCTION

Prince Edward Island lies in the southern part of the Gulf of St Lawrence in Eastern Canada, and is separated from New Brunswick, Nova Scotia and Cape Breton Island by the Northumberland Strait (Figure 1, frontispiece). The Island is approximately 230 km (145 miles) long and 6.5-50 km (4-35 miles) wide, and its surface rises to a maximum elevation of 127 m (425 feet) above sea level.

The earliest geological investigations of Prince Edward Island date back to the middle of the past century (Dawson 1842, 1874, 1878, 1891; Dawson and Herrington 1871; Ells 1883, 1885; and Gesner 1846). A comprehensive review of Island geology and its economic potential was completed by Milligan in 1949, following which the Geological Survey of Canada conducted detailed investigations on its surficial and bedrock geology over a 20-year period from 1953 (Crowl 1960a, 1960b, 1969; Crowl and Frankel 1970, Frankel 1960, Frankel and Crowl 1961, 1970; Prest 1962, 1964, 1972, 1973; Prest and Brady 1964; Prest et al. 1969).

Deep drilling in search of coal, oil and natural gas since the early part of this century has not only demonstrated the presence of a considerable thickness of Upper Paleozoic strata, estimated to be in excess of 10,000 m (30,000 feet) in the southeastern part of the Island (Howie and Cumming 1963), but has also aided in the stratigraphic interpretation of the basin (Barss et al. 1963; Barss and Hacquebard 1967; Hacquebard 1972; Howie and Barss 1974, 1975).

The aim of the present study was to subdivide the Prince Edward Island redbeds into lithostratigraphic units as a basis for further and more detailed geological studies, including those of an economic nature, and to respond to a need for a better understanding of the bedrock geology as an aid in elucidating the subsurface geology of the Island. Both aims have been realized, and Table 1 shows the lithostratigraphic units identified during the work. These are shown on the geological map, Map 1, at the back of this report.

This report details the initial results of two full seasons of fieldwork during the summers of 1977 and 1980, at which time all of the Island was remapped geologically. A limiting factor in studying the Island geology was found to be the low incidence of rock exposure: more or less continuous outcrops are only present in coastal sections, whereas inland exposures are rare except for a few road-cuts and gravel (conglomerate) pits. As a result, some of the present interpretations are to some extent tentative, and may be subject to change as further geological data are obtained.

The mineral resource potential of Prince Edward Island, excluding surficial deposits, is centred on four main commodities:

1. Uranium (and other metals)
2. Gravel from weathered bedrock
3. Hydrocarbons and coal
4. Salt.

The actual or potential presence of the first two, insofar as they are related to near-surface bedrock of the Island, have been a major impetus of this survey and will be discussed in some detail in this report. The potential for hydrocarbons, coal and salt is

essentially confined to the subsurface and is considered beyond the scope of the present investigation.

The surficial geology of Prince Edward Island has previously been reported on by Prest (1972), and others, and is not dealt with in this report.

PHYSIOGRAPHY

Prince Edward Island is formed of Permo-Carboniferous redbeds, tilted to the northeast at a low angle, its gently curving outline due to the change of strike from one end to the other. The western part of the Island is primarily lowland with gentle topographic elevations not exceeding 23 m (75 feet) above sea level and average land slopes ranging up to 4° (Brandon 1966). The central part is underlain by a northwesterly trending tract of hills with land slopes in excess of 8°, and a topography of rolling farm land with elevations up to 120 m (400 feet). Cuesta landforms, due to the presence of sandstone and conglomerate strata, can be identified.

The area to the east of Hillsborough Bay, also of rolling topography, has elevations of 30-75 m (100-250 feet), rising to nearly 120 m (400 feet) in one locality and relatively gentle land slopes ranging between 2° and 8° (Brandon 1966). In contrast, the area north and northeast of Charlottetown is prevailingly lowland, up to 60 m (200 feet) high, rising to 90 m (300 feet) in only a few isolated localities.

Bays and estuaries penetrate deeply into the Island; Egmont, Malpeque and Hillsborough Bays are the largest, and Hillsborough River the longest. These represent former river valleys that were submerged by the Holocene sea-level rise. Extensive sand beach and dune complexes fringe many of the bays along the north shore.

GEOLOGY

AGE OF THE STRATA

The age of the Prince Edward Island redbeds has in the past been the subject of considerable controversy. Dawson (1842) originally assigned an age similar to that of the coal measures of Nova Scotia, on the basis of the coal-measure type fossil flora contained in both sequences. He subsequently reversed his stand on the age of the redbeds on the Island, however, and over a period of three decades regarded their age as Carboniferous and possibly, in part, the equivalent of the Triassic sandstone of Connecticut (Dawson 1848). This dual age interpretation resulted from the initially incorrect identification of the vertebrate fossil *Bathygnathus borealis* Leidy, collected from a locality in central northern Prince Edward Island. Leidy (1854) assumed the species to be related to the bipeds which made the so-called bird tracks of the "New Red Sandstone" of Connecticut, casting serious doubt on the assigned Permo-Carboniferous age of the Island's redbeds. Nevertheless, a number of authors, including Dawson himself, periodically challenged such a young age, citing evidence from the fossil flora in support of a Permo-Carboniferous, or at least a Permian, age for the strata in the southern part of the Island (Bain 1881; Dawson 1855, 1891; Ells 18[illegible]). This conflict in age interpretation was not resolved until *Bathygnathus borealis* was properly identified as a pelycosaur having Permian rather than Triassic affinities (Case 1905, Huene 1905) after which all of the redbeds of the Island were assigned to the Permian (Langston 1963).

Results from subsequent work by Langston (1963) on vertebrate bone fragments collected from various Island localities generally supported the Lower Permian age inter-

Table 1

Lithostratigraphic Units Present in Prince Edward Island

MESOZOIC

MIDDLE TRIASSIC

Tholeiitic diabase.

UPPER PALEOZOIC

LOWER PERMIAN

Pictou Group ("Prince Edward Island redbeds"):

IV **Megacyclic Sequence IV** Redbeds; conglomerate and sandstone, fossil plants absent. Basal conglomerate has "mature" composition (quartz + quartzite 78-95%, rhyolite 0-14%, and roundness values 0.45-0.60).

III **Megacyclic Sequence III** Redbeds; conglomerate, sandstone and siltstone; fossil plants apparently absent. Basal conglomerate has "submature" composition (quartz + quartzite 51-69%, rhyolite 25-40%, and roundness values 0.35-0.52) in central parts of the Island, and "immature" in the southeast (quartz + quartzite 50-78%, rhyolite 0-8%, and roundness values 0.15-0.44).

CARBONIFEROUS

STEPHANIAN (UPPER PENNSYLVANIAN)

Pictou Group ("Prince Edward Island redbeds") (continued):

II **Megacyclic Sequence II** Redbeds; conglomerate, sandstone and siltstone; fossil plants and fern impressions locally present. Basal conglomerate has "submature" composition (quartz + quartzite 51-69%, rhyolite 25-40%, and roundness values 0.35-0.52) in central parts of the Island, and "immature" in the southeast (quartz + quartzite 50-78%, rhyolite 0-8%, and roundness values 0.15-0.44). May be in part Lower Permian.

I **Megacyclic Sequence I** Red and grey beds; sandstone and siltstone, minor conglomerate; fossil plants and fern impressions locally very common.

B **Pictou Group** (undivided): Grey conglomerate and sandstone, red sandstone and siltstone; coal measures locally present, fossil plants very common.

CARBONIFEROUS (undivided)

A Rocks older than Pictou Group, older Carboniferous strata.

DEVONIAN AND OLDER

Metamorphic basement encountered in drilling.

pretation for the redbeds in the central and northern part of the Island. A slightly older (Stephanian-Lower Permian) age, however, was obtained from fossil flora studies (Holden 1913, Darrah 1936) and from palynological data (Barss et al. 1963, Hacquebard 1972) in the southern and western parts of the Island. Although these dates appear at first glance to be conflicting, for a sequence of flat-lying strata, their stratigraphic relationships are confirmed by the present work which shows them to be slightly tilted to the northeast (1-3°) so that the oldest strata are exposed along the southern and western coasts of the Island, and the youngest along the central, northern and northeastern parts.

ROCK TYPES

Prince Edward Island is underlain by a coarsening-upwards sequence of terrestrial redbeds, flat-lying or dipping gently to the east, northeast or north. The only known occurrence of igneous rock is a tholeiitic diabase sill or dyke exposed on the northeastern extremity of George Island in Malpeque Bay.

Five major sedimentary and one igneous rock type make up the lithological spectrum of the Island:

1. Orange to dark-red silt and claystone
2. Pale grey to buff-grey fine grained limestone
3. Very fine to very coarse-grained red sandstone with minor intercalations of grey or greyish-green sandstone
4. Greyish-red intraformational mud-pellet conglomerate and chaotic breccia
5. Greyish-red quartz-pebble and cobble conglomerate
6. Tholeiitic diabase.

LITHOLOGICAL DESCRIPTIONS

Silt and Claystone

Orange-red to dark-red silt and claystone constitute an estimated 25% of the sedimentary rocks and widely underlie the western and southwestern parts of the Island as well as the Hillsborough Bay area. Silt and claystone units are up to 10 feet (3 m) thick and can be traced laterally over considerable distances. They are slightly calcareous and commonly exhibit hackley fracturing due to dehydration shrinkage. The silt and claystone are interbedded with orange to pale red, very fine to fine-grained sandstone, and minor medium-grained red sandstone.

Several red shale occurrences on the Island have in the past been tested for the manufacture of common brick and drain tile. Ceramic tests on shale from Beacon Point along the northwestern shore of Hillsborough Bay indicated the strata to have suitable properties for certain brick and tile products (Prest and Brady 1964).

Limestone

The majority of recorded limestone occurrences are of relatively impure calcitic or marly intraformational mud-pellet conglomerate rather than limestone.

Relatively pure limestone is rare on the Island and, where found, occurs primarily in association with the fine-grained lithologies (silt and claystone). The best known

occurrence is a thin bed of red mottled grey-buff limestone exposed on the shore at low tide around the north side of Little Miminegash Pond, on the west coast. It occurs offshore for a short distance and presumably also extends for some distance landward at a shallow eastward dip of approximately 3°.

Float of a similar dense fine-grained greyish-buff limestone was observed at the base of a cliff 3 m (10 feet) high along the shore near the village of Cap Egmont. The local succession comprises alternating beds of very fine-grained red sandstone and siltstone. The limestone probably represents a fresh-water lacustrine deposit; the lateral extent of this occurrence is not known but, as lacustrine facies on floodplains tend to be limited in size and thickness, it is not expected that this limestone bed has any great lateral continuity. Fossils were not observed in the limestone float, although the lithology is very similar to the limestone at Little Miminegash Pond, which yielded the fresh water ostracod *Carbonita inflata* (Copeland 1957).

Occurrences of argillaceous limestone have previously been reported from Park Corner, Bayview near Grand River, Maple Plains, and Mount Carmel in the west central part of the Island, and Orwell Point and Earnscliffe on Hillsborough Bay (Milligan, 1949). The majority of these occurrences would probably be classed in the present study as carbonate-cemented marly mud-pellet conglomerate rather than limestone.

Sandstone

Sandstone, ranging in grain size from very fine to very coarse, is the dominant lithology of the Island and underlies an estimated 60% of the surface area.

Depending on grain size, the sandstone varies in colour from pale orange (fine to very fine sandstone) to dark purplish-red (medium to very coarse sandstone) with local intercalations of grey, greyish-red or greenish-grey sandstone. The latter can usually be attributed to reduction (or non-oxidation) of the hematitic matrix: it occurs as discontinuous lenses within the sandstone-siltstone sequence in the form of thin zones parallel to and along joint planes, as haloes around clay galls and mudstone breccia, as reduction spheroids in very fine sandy siltstone, or as zones up to 60 cm (2 feet) thick at the base of sandstone units overlying siltstone.

The coarsest sandstone fractions are widely interbedded with intraformational mud-pellet conglomerate, mudstone breccia and/or quartz-pebble conglomerate, whereas the finer grained sandstone beds occur in association with silt and claystone.

The sandstone is arkosic in composition and commonly contains mica along lamination planes. Under the microscope, the sandstone can be seen to consist of approximately 70% clastic particles and 30% matrix. The clastic fraction is made up of 45-60% angular to sub-angular quartz, 20-30% feldspar, 10-20% lithic fragments, 5-10% mica and 5% specular hematite. The matrix is primarily hematitic clay-silt with considerable carbonate cement.

Intraformational Mud-pellet Conglomerate and Chaotic Breccia

Mud-pellet conglomerate and chaotic breccia are separate occurrences of intraformational clastic rocks of differing origins. Mud-pellet conglomerates are carbonate-cemented and occur as more or less continuous units in association with medium and coarse-grained red sandstone and/or quartz-pebble conglomerate. In contrast, chaotic breccias are not usually cemented and occur as discontinuous lenses in medium to fine-grained sandstone. Combined, they make up an estimated 10% of all redbed strata on the Island.

Intraformational mud-pellet conglomerate

The mud-pellet conglomerate varies from dark purplish-red to greyish-red and greenish-grey in colour and is characterized by the presence of sub-angular to sub-rounded clasts of more-or-less lithified silt or marl, set in a coarse-to-medium-grained, poorly sorted, friable sandstone matrix.

Two sub-types can be recognized in the mud-pellet conglomerate:

1. **Mud-pellet conglomerate containing lithified marl fragments in a carbonate-cemented sandstone matrix.** Individual fragments or clasts may be 25-100 mm (1-4 inches) in diameter. This rock type comprises relatively hard and competent strata which form laterally persistent units up to 4.5 m (15 feet) thick. It is commonly found at the base of major thick-bedded conglomerate and/or sandstone sequences (the megacyclic sequences, see p. 9) showing the effects of extensive scouring at the base of these units. Discontinuous lenses and horizons of thick-bedded quartz-pebble and cobble conglomerate occur widely in association with the well-cemented mud-pellet conglomerate, forming mappable lithostratigraphic units that can be traced for considerable distances in outcrop.

2. **Mud-pellet conglomerate of sub-angular to sub-rounded marly siltstone clasts in a partially cemented sandstone matrix.** Individual siltstone clasts may range up to 50 mm (2 inches) in diameter. This type of mud-pellet conglomerate occurs at or just above the base of individual channel sandstone units, overlying siltstone. The mud-pellet conglomerate makes up individual sedimentation units up to 1 m (40 inches) thick, is strongly cross-bedded, and is laterally restricted to fluvial channel sequences.

Petrographic examination of mud-pellet conglomerate reveals its composition as clastic particles 70%, carbonate cement 30%. The clastic particles range in size from coarse sand to granules and small pebbles and include the following compositions: quartz 35-45%, feldspar 5-15%, rock fragments (granules and small pebbles) 20-30%, intraformational mud-pellets 20-30%.

Chaotic breccia

In contrast to the mud-pellet conglomerate, chaotic breccia consists of angular clasts of sandstone or sandy siltstone in a matrix of similar composition and grain size. Individual clasts may range up to 100 mm (4 inches) or more in diameter, are poorly sorted, and lack evidence of wear by abrasion in sedimentary transport (Figure 17, p. 32). They form erratic and discontinuous lenses in medium-grained red sandstone and vary in lateral continuity from a few to about 100 m (300 feet). In a few instances chaotic breccia, still showing outlines of original cross-bedding, can be seen to grade into a medium-grained cross-bedded sandstone that is unaffected by brecciation (Figure 18). Clastic breccia pipes may locally occur in association with chaotic breccias (Figure 19).

Pebble and Cobble Conglomerate

Pebble and cobble conglomerates make up an estimated 5% of the total redbed outcrop of the Island. They occur as discontinuous lenses and beds within well-cemented mud-pellet conglomerate and/or coarse to very coarse sandstone at the base of megacyclic units.

Individual clasts range in size from less than 25 mm (1 inch) in small-pebble conglomerate, to 150 mm (6 inches) in cobble conglomerate.

Quartz pebbles, because of their milky-white colour, usually appear prominent, but may not be the dominant lithology. In addition to quartz, very fine-grained dense quartzite and rhyolite are the dominant lithologies, whereas chert and a small miscellaneous group of a few igneous and metamorphic pebbles make up the minor constituents. The matrix is coarse to very coarse-grained, poorly sorted sandstone and/or mud-pellet conglomerate. Carbonate cement is widely present.

Fifty-eight separate exposures have been analysed for roundness and composition of their pebble component. Roundness (Rho factors) of pebbles, based on visual comparison with images of known Rho factors, were found to range between Rho 0.17-0.60 (on a scale of 0 to 1).

The compositional characteristics of quartz-pebble conglomerates from the Island, expressed as zones one standard deviation from mean, have been plotted on a ternary diagram (Figure 2) with their three major components quartz, quartzite and chert forming the mature end-member, rhyolite as the intermediate, and miscellaneous (mainly metamorphic, igneous and sedimentary lithologies) as the immature end-member. For purposes of comparison, Figure 2 also shows compositional limits of a typical immature fanglomerate (Hopewell Group

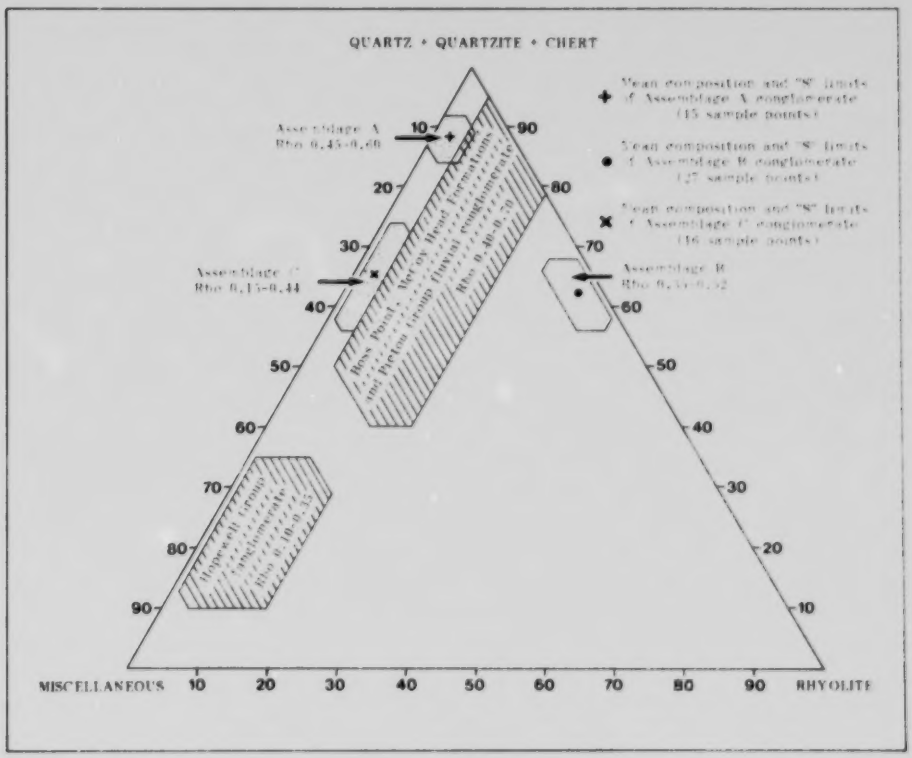


Figure 2 Carboniferous conglomerate compositions from southern New Brunswick and Prince Edward Island (Assemblages A, B and C), showing limits of one standard deviation.

of southeastern New Brunswick) and of typical fluvial conglomerates (Boss Point and McCoy Head Formations and Pictou Group of central and southern New Brunswick).

The Prince Edward Island conglomerates have several important characteristics:

1. They form three major assemblages (A, B and C) reflecting their compositional and roundness variations.

2. Assemblage B is anomalously high in its rhyolite content, not only with respect to other conglomerates from the Island (Assemblages A and C) but also in comparison with the slightly older Pictou conglomerates from southern and central New Brunswick, and

3. Their compositional maturity, based on the proportion of quartz + quartzite + chert, is within the range of the Pennsylvanian conglomerate formations of New Brunswick, and is significantly higher than the Upper Mississippian alluvial fanglomerates of southeastern New Brunswick.

The generally mature composition of the Assemblages A, B and C conglomerates, in combination with their intermediate Rho factors, strongly suggest a fluvial origin. Assemblage C conglomerates are confined to the southeastern coastal area. They are not only the least mature in composition but also show the lowest degree of roundness of all the bedrock conglomerates on the Island; blade and roller pebble shapes, as well as more equant ones, are common. They probably reflect a different and less-distant source area with respect to the other conglomerates. This interpretation is supported by the observation that Assemblage C conglomerates of the Kilmuir Syncline area locally contain a small percentage (<10%) of soft and friable Carboniferous sandstone and rare gypsum pebbles.

The conglomeratic units, though laterally extensive, are not necessarily uniform in thickness or continuous; they vary from thin pebbly lenses in sandstone to massive conglomerate beds.

Tholeiitic Diabase

The only verified surface occurrence of igneous rock on the Island is an aphanitic diabase on the northeastern tip of George Island (also known as Hog Island) in Malpeque Bay. The diabase is either regarded as a dyke (Milligan 1949), or a sill dipping east at approximately 15° (Prest 1972), terminating at its northern extension by a northeasterly striking shear zone (Milligan 1949). Prest (1972) considered the shear zone to be a footwall breccia because it included irregular bodies of "baked" sandstone, and much of the red breccia is seen to consist of greyish rock fragments up to 6 mm (¼ inch) in diameter in a fine-grained variable reddish matrix.

Although the contact zones between the diabase and enclosing sandstone are diffuse, the original thickness of the intrusion is believed to be approximately 3 m (10 feet) (Milligan 1949).

The rock is very fine grained, containing small phenocrysts of olivine, partially altered to chlorite, set in a felted mass of bytownite plagioclase and clinopyroxene (Prest 1972, Wanless et al. 1973). Whole-rock K-Ar ages of approximately 210 ± 30 m.y. indicate the rock to be middle Triassic in age (Wanless et al. 1973).

LITHOSTRATIGRAPHY

The redbeds of Prince Edward Island range from Stephanian to middle Early Permian in age, and are provisionally assigned in this report to the Pictou Group of New Brunswick and Nova Scotia, of Middle Pennsylvanian-Stephanian age. The tentative upward extension of the Pictou Group to include all the redbeds on the Island, here proposed, is justified by several criteria: the absence of any recognizable structural or stratigraphic break between the redbeds and the underlying mainly grey beds (Barss et al. 1963, Hacquebard 1972); the lithological similarity (other than for the much greater proportion of red colour and the absence of coal); and the apparently time-transgressive nature of the upward transition from grey to red beds, as recognized from borehole intersections in Island wells and surface exposures in eastern New Brunswick.

As a means of differentiating the redbeds from the coal measures beneath, the redbed sequence is informally referred to in this report as the "Prince Edward Island redbeds". It may be found desirable in the future to define the stratigraphy in terms of a group consisting of four formations, based upon the Megacyclic Sequences (dealt with below) and two members, based upon the two Subcyclic Sequences.

Little attempt has previously been made to subdivide the redbeds into mappable lithostratigraphic units, except on a local scale in the southeastern part of the Island (Frankel 1966), largely because of the apparent flat-lying nature of the strata, abrupt internal facies changes, and the presumed absence of recognizable marker horizons.

Using a different approach to lithostratigraphic mapping, however, the present work indicates that the Prince Edward Island redbeds can be subdivided into at least four lithostratigraphic units in the form of major fining-upward cyclic sequences. Informally referred to as Megacyclic Sequences I to IV, each unit is made up of a spectrum of lithologies ranging from greyish-red pebble and cobble conglomerate at the base, through reddish-brown coarse to fine sandstone in the middle, to orange-red very fine sandstone, siltstone and claystone at the top. Each megacyclic sequence is at least 275 m (900 feet) thick and in turn is made up of smaller-scale cycles comprising partial to complete fining-upwards fluvial sequences. Subcyclic sequences, resembling megacyclic sequences but on a smaller scale, are locally present as well.

The presence of basal pebble and cobble conglomerates, and their lithological and morphometric characteristics, adds considerably to the lithostratigraphic subdivision of the redbeds. Mapping has shown that the rhyolite-rich conglomerates of Assemblage B are confined to Megacyclic Sequences II and III, whereas basal conglomerates of Megacyclic Sequence IV are characterized by the low rhyolite composition of Assemblage A. Conglomerates of Assemblage C, lying on strike with Assemblage B conglomerates of Megacyclic Sequence III, are confined to the southeastern part of the Island.

Only a few small-pebble lenses are present in the sandstone of Megacyclic Sequence I (Subcylic Sequence 1A). Although too few for an accurate interpretation, tentative observations tend to indicate that the conglomeratic lenses are low in rhyolite content and similar in compositional maturity and roundness to the Pictou Group conglomerates of New Brunswick.

These cyclic sequences in the Prince Edward Island redbeds have similar characteristics to those previously recognized in the slightly older Pictou strata of New Brunswick

(Poll 1970, 1973, LeGallais 1983). In contrast to those of the Island, however, each New Brunswick megacyclic sequence is characterized by grey instead of red conglomerate and/or sandstone at the base, fining upwards through medium to fine-grained grey and red sandstone capped by red siltstone at the top. In addition to colour, the Island redbeds also differ from Pictou strata of New Brunswick and Nova Scotia by the absence of coal; coal-measure-type plant fossils, however, are locally present in the finer grained lithofacies of Megacylic Sequences I and II of the Prince Edward Island redbeds; several of these are of the same species as those occurring in the Pictou Group of Cape Breton, Nova Scotia and New Brunswick (Dawson and Herrington 1871). Drilling results (Appendix 1) indicate that the red and grey Pictou coal measures of New Brunswick and Nova Scotia occur at depth beneath the Island (Figure 22, p. 36) and that these strata grade conformably upward into the redbeds exposed at the surface (Barss et al. 1963, Hacquebard 1972, Barss et al. 1979).

Although lithostratigraphic subdivision of the Prince Edward Island redbeds into megacyclic sequences has proven to be feasible, present stratigraphic practice does not lend itself readily to the formal designation of multi-lithology (i.e. cyclic) stratigraphic units. Further subdivision of whole megacyclic sequences into smaller units with greater lithological uniformity, though feasible, would ignore the gradually fining-upwards nature and lithogenetic affinity of the strata within each sequence. As a result, lithostratigraphic boundaries would have to be defined on the basis of clastic ratios or some other arbitrary limit. In contrast, use of whole megacyclic sequences as mappable lithostratigraphic entities allows each unit to be defined by their fining-upward range of lithologies, their coarse conglomeratic bases and their mainly disconformable upper and lower contacts. Under conditions where the various lithologies are not laterally consistent, but represent rapidly changing facies of recurring fluvial cycles, it was found that whole megacyclic sequences do constitute the smallest practical lithostratigraphic unit of the Prince Edward Island redbeds, notwithstanding their considerable thickness. Experience has shown that this method of mapping whole fining-upward cyclic sequences has greatly improved the understanding of an extremely difficult sequence of rocks that had previously defied all attempts at subdivision except on a local scale.

In addition to the megacyclic sequences, smaller-scale cyclic sequences with similar overall characteristics as the megacyclic units have been mapped, where their lateral continuity appears to warrant designation as subcyclic sequences equivalent in status to members. Thus Megacyclic Sequence I along the western coast of the Island is locally subdivided to include Subcyclic Sequence IA, and Megacyclic Sequence III in the area immediately east of Hillsborough Bay includes Subcyclic Sequence IIIA.

The present subdivision of the Prince Edward Island redbeds and the mapped distribution of four megacyclic lithostratigraphic units is not only fundamental to the improved knowledge of the Island but also support Langston's (1963) interpretations that:

1. The ages of the rocks differ from place to place
2. The oldest known strata occur in the southern and western parts of the Island
3. Younger beds appear in the north-central part
4. There is no evidence of the presence of Triassic rocks (except for the diabase sill at George Island).

In addition, present lithostratigraphic work demonstrates the lateral and vertical relationships of the strata, which were previously unknown, and also shows that the youngest Permian rocks not only occur in the central, northern and northeastern coastal region of the Island but also reappear as an outlier in the axial zone of the Kilmuir Syncline.

Although the degree of chronostratigraphic unity of the megacyclic units of the Island has not yet been confirmed, integration of present with previous work suggests that the Carboniferous-Permian transition lies at about the level of Megacyclic Sequence II. The apparently conformable nature of the strata and their uniformity of sedimentary characteristics with respect to the underlying grey sequence suggest that sediment accumulation in the Island area continued across this system boundary with no obvious interruption.

Four fining-upwards megacyclic sequences comprising mappable lithostratigraphic units have been tentatively identified and mapped (Figure 1, frontispiece, and Map 1, back of the report). The whole succession is slightly tilted at angles of 1-3° towards the east-southeast in the western part of the Island and between horizontal and 7° between northwest and northeast, and southeast, in the remaining areas. Maximum dips of 12° southeast were measured in a coastal cliff section immediately east of Cape Tryon. The structural picture is summarized in Figure 1 (frontispiece).

The cyclic nature of the lithostratigraphy is demonstrated at all scales by the presence of characteristic asymmetrical upward-fining cycle types, particularly the aforementioned megacyclic and subcyclic sequences; these are themselves made up of repeated occurrences of partial to complete upward-fining fluvial cycles, some as small as a single bed, others as thick as 20 m (60 feet).

Megacyclic Sequence I (MS.I)

The outcrop of Megacyclic Sequence I lies in Prince County, extending from North Cape to West Point, around Egmont Bay into Bedeque Bay; from there it runs offshore beneath the waters of the Northumberland Strait. Exposures that make up Governor's Island in Hillsborough Bay is also considered to belong to this sequence.

The top of MS.I, including Subcyclic Sequence IA (SS.IA), where present, is disconformably overlain by coarse to very coarse mud-pellet and quartz-quartzite-rhyolite conglomerates (Assemblage B) of Megacyclic Sequence II (MS.II). The disconformable erosional contact between the two sequences is well exposed around North Cape; dips are towards the southeast, northeast and northwest at very low angles, mainly between 1° and 3°.

The vertical extent of the redbeds in MS.I is recorded in the core of Prince Edward Island Government Well No 5 near Miminegash (see Figure 22, p. 36, and Appendix 1) where the transition from coarser-grained grey strata to redbeds reportedly occurs at depths between 220 and 290 m (730-950 feet), below which all strata were grey (Ingall 1909). The grey-to-red transition is also exposed in what are probably MS.I strata just west of Cape Tormentine, New Brunswick, and re-occurs around Governor's Island in Hillsborough Bay. Alternations of red sandstone, mud-pellet conglomerate and siltstone predominate in MS.I; conglomerate with extra-basinal rock fragments is absent except for a few isolated small pebble lenses in mud-pellet conglomerate along the base of SS.IA. Fining-upward cyclic sequences of fluvial origin are present, up to 15 m (50 feet) thick.

Plant-fossil imprints, including those of fossil ferns similar to ones found in the Pennsylvanian coal measures of Nova Scotia, have previously been observed in the red beds of Miminegash and elsewhere (Dawson and Herrington 1871, Bain 1881, Bain and Dawson 1885), suggesting a Stephanian (Darrah 1936) or Permian (Holden 1913) age for the strata along the west coast of the Island. A Stephanian age for the redbeds is also suggested by the occurrence of the bivalve *Carbonita inflata* in a non-marine limestone bed at Little Miminegash Pond, which Copeland (1957) recognized as a Carboniferous species occurring in Pictou (Pennsylvanian) rocks of Nova Scotia and New Brunswick.

Based on megafloral and palynological evidence respectively, an age of Upper Pennsylvanian (Westphalian D, Gussow 1953) or Stephanian (Barss et al. 1963, Barss and Hacquebard 1967) has previously been assigned to the grey strata of eastern New Brunswick, and at depth beneath the Island, just below the grey-to-red transition.

Pennsylvanian-Stephanian spores reportedly occur in the following wells, all of which intersect MS.I strata at the surface (after Prest 1962, Barss et al. 1963, Hacquebard 1972):

Well Location	Depth of Sample	Age Indicated by Miospores
Wellington Station No 1	527 m (1,730 feet)	Stephanian
	777-1,210 m (2,550-3,970 feet)	Westphalian D
Port Hill No 1	524-530 m (1,720-1,740 feet)	Stephanian
	870 m (2,850 feet)	Westphalian C & D
MacDougall No 1	3-885 m (10-2,900 feet)	Stephanian
	936 m (3,070 feet)	Westphalian C & D
MacDougall No 1A	551 m (1,809 feet)	Stephanian

Plant-fossil imprints were found to be widely present all along the west coast of the Island, in particular within the finer-grained red lithofacies at the top of MS.I and SS.IA. The plant fossils are only preserved as imprints in sandstone and siltstone, however, and consequently most of the critical details of identification are not observable (Figures 3, 4 and 5). Cuticular material has not been found, and only an occasional specimen has a black stain in the matrix delineating the outlines of the pinnules. Nearly all of the plants are preserved as faint impressions on bedding surfaces, and therefore only gross morphological features remain on which to base identification. Fortunately, reasonably significant identifications can be made based on the shape and size of the pinnules, as these characteristics are quite diagnostic. One specimen collected (*Walchia* sp.) showed remarkably good preservation as a barite replacement (W.H. Forbes, personal communication 1980).

The plant-fossil assemblage is relatively meagre, represented by only a few taxa and dominated by abundant *Pecopteris arborescens* (Figure 3) and slightly less abundantly by *Walchia gracilis* (Figure 4) and *Walchia robusta* (Figure 5). Collections made during the 1977 field season contained one fragmentary specimen apparently assignable to *Cordaites* sp., as well as a number of other fossil plants too fragmentary to be useful. *Walchia*, once considered to be an exclusively Permian form, is now thought merely to have become more abundant during Permian times (Elias 1936, p. 692). *Walchia* has occasionally been found in the Stephanian of western Europe, England and Nova Scotia (Bell 1938); it also occurs in late Pennsylvanian strata of North America but is more abundant in early Permian rocks where they are characteristic fossils of the redbeds of Kansas, West Virginia, Oklahoma and Texas, as well as beds of similar age elsewhere (W.H. Forbes, personal communication 1980).

Judging from the close stratigraphic relationships of the strata at Cape Tormentine and at shallow depth across the Northumberland Strait, in conjunction with the palynological data obtained from well samples at shallow depth in western Prince Edward Island,

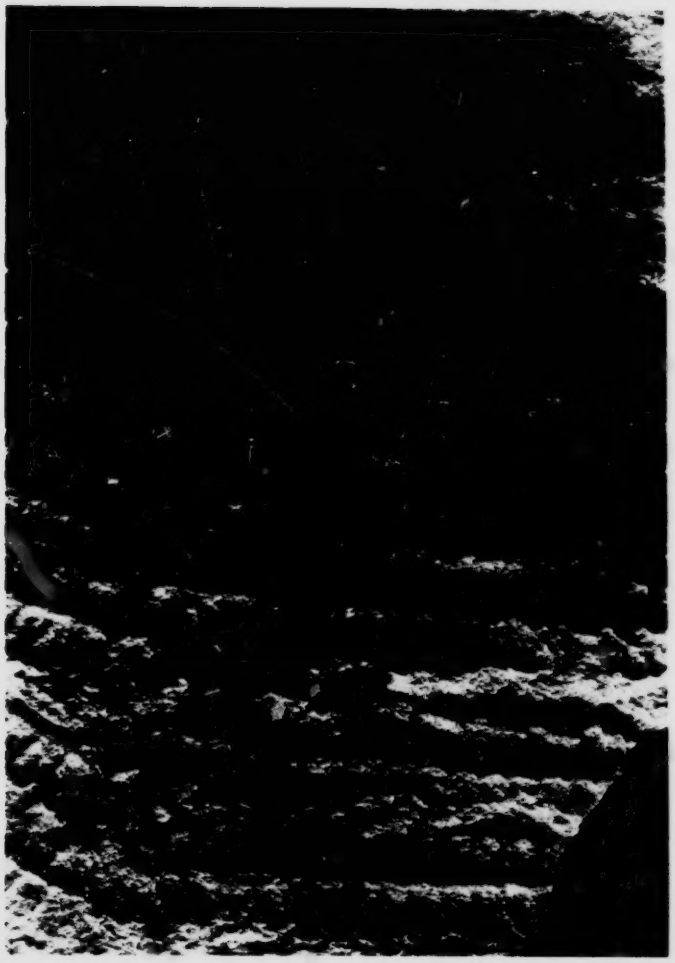


Figure 3 Imprint of *Pecopteris arborescens* in red sandstone, Subcyclic Sequence IA, 10 km south-west of North Point, west coast of Prince Edward Island (approx. natural scale). Identification by W.H. Forbes.

Figure 4 Imprint of *Walchia gracilis* in red silty sandstone, Subcyclic Sequence IA, 10 km south-west of North Point, west coast of Prince Edward Island (approx. natural scale). Identification by W.H. Forbes.

Figure 5 Imprint of *Walchia robusta* in red silty sandstone, Subcyclic Sequence IA, 10 km south-west of North Point, west coast of Prince Edward Island (approx. natural scale). Identification by W.H. Forbes.

it would seem than an Upper Pennsylvanian-Stephanian age is justified for the redbeds of the lowest megacyclic sequence (MS.I). Stephanian age rocks have also been reported from the centre of Hillsborough Bay (Governor's Island, Barss et al. 1963) and probably belong to MS.I as well.

Subcyclic Sequence IA (SS.IA)

Subcyclic Sequence IA lies at the top of Megacyclic Sequence I along the western coast of Prince Edward Island. The base of this sequence, equivalent in status to member, extends from just north of Miminegash south to Campbellton, where its characteristic mud-pellet conglomerate containing a few small-pebble lenses overlies orange-red siltstone of MS.I (Figure 6). SS.IA comprises a fining-upward succession of redbeds, consisting of sandstone, mud-pellet conglomerate and siltstone, that merge laterally with the unsubdivided redbeds of MS.I.

Megacyclic Sequence II (MS.II)

Megacyclic Sequence II is the lowest lithostratigraphic unit of formation level in Prince Edward Island for which both base and top can be mapped, presenting a complete sequence of lithofacies for examination. Its outcrop extends from the northwestern tip of the Island (North Cape) through Malpeque Bay into the Hillsborough Bay area; it reappears in coastal exposures at Murray Head, southeastern Kings County.

Extensive quartz-quartzite-rhyolite conglomerate beds (Assemblage B) occur in, or just above, the basal calcareous mud-pellet conglomerate, disconformably overlying the fine-grained sandstone and siltstone top strata of MS.I. The conglomerate is particularly well exposed at North Cape (Figure 7); its characteristic high content of rhyolite pebbles can be traced through intermittent coastal and inland outcrops, the latter mainly gravel pits over a distance of some 100 km (66 miles) to the southeast, as far as Bedeque Bay in southern

Figure 6 Basal contact of red sandstone, mud-pellet and small-pebble conglomerate of Subcyclic Sequence IA with underlying red siltstone and very fine sandstone of Megacyclic Sequence I, just north of Campbellton, west coast of Prince Edward Island.

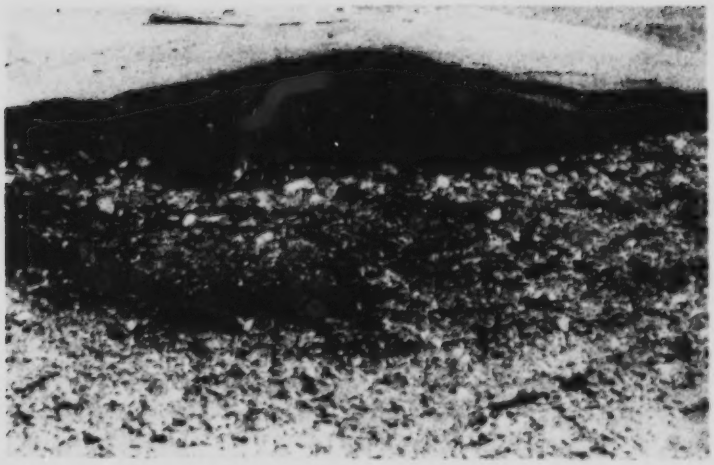


Figure 7 Quartz-quartzite-rhyolite conglomerate at the base of Megacyclic Sequence II at North Point.

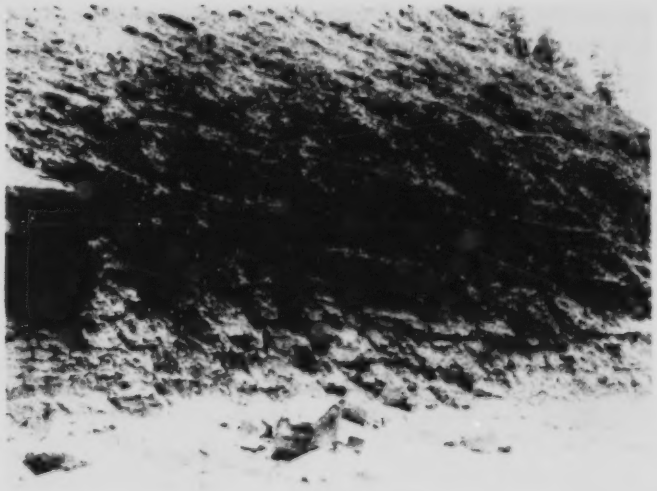


Figure 8 Fine-grained upper part of Megacyclic Sequence II, along the Hillsborough Bay shore of the Point Prim peninsula.

Prince County where there are good exposures on Seacow Head. The conglomerate extends out under Northumberland Strait, where it has been encountered in sediment sampling.

The fine-grained sandstone and siltstone of MS.II are well exposed in the cliffs just west of Rice Point, west of Charlottetown, and along the southeastern shore of Hillsborough Bay from Orwell Bay to Point Prim (Figure 8).

MS.II locally contains fossil-fern imprints at Rice Point, similar to those found in MS.I along the west coast. Poorly preserved plant stems are present, replaced either by silica, barite or both, in particular in the De Sable area in western Queens County and at Gallas Point* on Hillsborough Bay.

Spore data obtained from purplish-grey strata near the top of a borehole at Gallas Point (Earnscliffe No 1), however, indicate an early Permian age, rather than Stephanian (Barss et al. 1963, Hacquebard 1972), for the strata around the shores of Hillsborough Bay now included within MS.II. This age interpretation is also supported by the presence of vertebrate fossils obtained from a number of localities around the bay, also indicating an early Permian age (Langston 1963). In view of the proximity of Stephanian strata on Governor's Island and laterally on strike, it would seem prudent to assign a Permo-Carboniferous age for these beds. On very tenuous evidence, Langston (1963, p 29) concluded that fossiliferous beds at Seacow Head were the same age as those around Hillsborough Bay. The present lithostratigraphic study supports this contention, as beds at Seacow Head and the Hillsborough shores all belong to MS.II.

The early Permian spore date for the strata around Gallas Point was obtained from purplish-grey, rather than red, strata. Purplish-grey intervals elsewhere in the sequence occur at the grey-to-red colour transition and have been intersected within Stephanian-age strata at a depth of approximately 220 m (730 feet) in a borehole along the western coast of the Island (P.E.I. Government Well No 5, Ingall 1906); at a depth of approximately 500 m (1,650 feet) in several boreholes just west of Malpeque Bay (Port Hill No 1, MacDougall No 1 and 1A, and Wellington Station No 1; Barss et al. 1963); and also occur around Governor's Island and along the shore of Cape Tormentine, New Brunswick (Gussow 1953). The early Permian age for the purplish-grey interval exposed around Gallas Point, therefore, indicates a considerably younger age for the colour transition than elsewhere in the Pictou Group, suggesting that the grey-to-red transition is time-transgressive over a thickness greater than at least one whole megacyclic sequence. The colour change is probably diagenetic and may have been dependent on a certain minimum organic content in the sediments at the time of deposition. If so, it would have no stratigraphic significance and the change in colour should only be used as an informal means of separating the Prince Edward Island redbeds from the older red and grey Pictou strata below.

Megacyclic Sequence III (MS.III)

Megacyclic Sequence III occurs in the central and eastern parts of the Island. The erosional contact of its basal conglomerate with the fine-grained upper part of MS.II is exposed in the southeastern cliffed shore of Hillsborough Bay; from here, following a change of strike around the Kilmuir Syncline, the basal conglomerate (Assemblage C) can be traced in extensive cliff exposures to the east along the coast through Wood Islands and Murray Harbour to Cardigan Bay, and into the Souris area of Kings County.

Contact relationships between MS.II and MS.III are not as well documented in the central part of the Island, west of Charlottetown; there the lower limits of MS.III had to

* Also known as Gallows Point

be interpreted from intermittent exposures of its characteristic quartz-quartzite-rhyolite conglomerates (Assemblage B) in pits and coastal exposures.

The relationship between the conglomerate outcrops of the southeastern coastal area and the central southern part of the Island (western Queens County, west of Charlottetown), is not entirely clear. Mapping has revealed significant differences between the two major conglomerate occurrences (Assemblages B and C), in terms of roundness and composition, within the same stratigraphic interval. The conglomerates west of Charlottetown show intermediate clast roundness (Rho 0.35-0.52) and have the characteristic high rhyolite content of Assemblage B (25-45%), whereas the conglomerates of the southeastern coastal area are low in rhyolite (0-8%) and considerably less rounded (Rho 0.15-0.44). Nevertheless, careful mapping of the strata around Hillsborough Bay suggests that the two conglomerate beds occupy approximately the same stratigraphic position.

The observed differences in composition and roundness of the Assemblages B and C conglomerates may reflect separate source areas with different bedrock characteristics. Frankel (1966) first mapped the southeastern conglomerate outcrops, drawing attention to the apparent low degree of rounding and heterogeneous composition of its clasts. He attributed the conglomerate to rapid uplift and erosion of a source area that could probably be found in the highlands of Nova Scotia, to the south of outcrop area. Although this interpretation would require further confirmation from more detailed provenance studies, the dual-source concept for the conglomerates (and hence for the enclosing redbeds in general) appears attractive. It is tentatively supported by paleocurrent orientation data of the more mature conglomerates in central and western Prince Edward Island, which show derivation from a distal source to the southwest, probably southwestern New Brunswick or beyond, whereas cross-bedding directions in southeastern Prince Edward Island suggest derivation from the south (Figure 10, p. 25) as suggested by Frankel (1966).

Neither spores nor plant fossil imprints have been found in MS.III, except for a few questionable forms resembling plant stems, replaced by barite. A few vertebrate fossil fragments have previously been collected from strata now assigned to the top of this sequence, but these indicate an early Permian age (early Artinskian, Langston 1963) slightly younger than the strata around Hillsborough Bay (Sakmarian, Barss et al. 1963).

Subcyclic Sequence IIIA (SS.IIIA)

This sequence, with a status equivalent to member, occurs in the upper part of MS.III in the southeastern part of the Island. Its basal coarse sandstone and conglomerate (Assemblage C) which overlies red siltstone of MS.III has been traced from coastal and inland exposures (gravel pits) from just southeast of Pinette Harbour in southern Queens County eastward to beyond the town of Murray River. Further northeast the conglomerate horizon merges with a similar one occurring stratigraphically lower in MS.III, and beyond this point both extend through intermittent coastal exposures north and northeast in to the Souris area. The two conglomerate beds also merge north of Pinette Harbour, and in the Orwell Bay area they are seen only as thin intermittent lenses of small-pebble conglomerate that cannot be traced any further north than Orwell Bay.

Megacyclic Sequence IV (MS.IV)

The full succession of Megacyclic Sequence IV is not present on the Island, its top lying beneath the waters of the Gulf of St Lawrence. The part exposed consists essentially of a basal quartz-quartzite conglomerate (Assemblage A) followed by coarse-to-medium sandstone. Its outcrop is mainly restricted to the central northern coastal areas of Queens and Kings Counties, but it reappears as an outlier of coarse basal conglomerate in the axial

zone of the Kilmuir Syncline. In contrast to the stratigraphically lower conglomerates, those of MS.IV are characterized by well-rounded pebbles (Rho 0.45-0.60) in combination with a low rhyolite content (0-13%).

The mapped distribution of MS.IV is tentative and, due to lack of inland exposures, is mainly interpreted from isolated occurrences of its characteristic basal conglomerate in gravel pits and coastal exposures. The sequence's disconformable lower contact with the fine-grained silty redbeds of the top of MS.III can be seen in the steep cliffs just south of East Point. The conglomerate is absent here, however, and the basal beds of MS.IV are thick-bedded medium-to-coarse sandstone, overlying siltstone and fine-grained sandstone of the lower sequence.

Frankel (1966) mapped the extensive conglomerates of the Kilmuir Syncline area in the southeast of the Island, and initially suggested the presence of a regional angular unconformity between his Unit C (MS.IV) and Unit B (MS.III), principally because:

1. Characteristic conglomerates of MS.III are laterally continuous, which he attributed to folding and erosion prior to deposition of MS.IV; and
2. Strata of both MS.III and MS.IV in the district seemed to differ in their bedding attitudes (Frankel 1966, p 24).

However, in a subsequent footnote, (Frankel 1966, p 25) recognized that lateral discontinuity of the MS.III conglomerates, rather than reflecting folding and erosion prior to deposition of the overlying conglomerate, might also be explained by the lateral "pinch out" of MS.III conglomerates, in which case, he stated, the contact between the two units would be disconformable rather than angular-unconformable. Initial results of the present study tend to support Frankel's "pinch-out" explanation as the more likely cause of the lithological change. The thick coarse conglomerate beds of MS.III centred on Wood Islands can be seen to change laterally and gradually to relatively fine-grained pebbly sandstones around Pinette Harbour, rather than terminating abruptly.

The apparent difference in bedding attitudes between the two units, cited by Frankel as additional support for the concept of a regional angular unconformity, can also be explained by a lateral change of dip from inclined to horizontal. This dip change takes place around the Kilmuir Syncline which, rather than being a conventional syncline due to compression, is more accurately described as a structural basin of mainly flat-lying strata flanked by two salt-cored anticlines trending east-northeast: these are the Gallas Point and Wood Islands Anticlines, lying to the northwest and southeast respectively. Basal conglomerates of MS.III (Frankel's Unit B) are exposed along the domed-up flanks of the two anticlines, whereas the basal conglomerates of MS.IV (Frankel's Unit C) occupy the central, relatively undisturbed zone between the two anticlines - hence the apparent difference in bedding attitudes.

Judging from the generally conformable contact relationships of the strata throughout the Island, in combination with the above explanation for the apparent lithological and structural relationships of the strata in the southeast, this report concurs with Frankel's (1966) alternative interpretation, namely that, due to lateral pinch-out, the base of MS.IV is disconformable rather than unconformable with respect to MS.III.

A few vertebrate fossils were previously reported from strata in northern Queens County, now assigned to MS.IV. Most notable among them is the type specimen of *Bathygnathus borealis* Leidy, discovered during the digging of a well in about 1845. The original site is said to have been relocated by Dr V.K. Prest of the Geological Survey of Canada, 2.8 km

(1¾ miles) south of Cape Tryon lighthouse in the French River district (Langston 1963). The age of the vertebrate fossils is believed to be approximately early Artinskian, younger than the Early Permian strata of the Hillsborough Bay area (Langston 1963, p.28). On the basis of this information, and considering the apparently conformable relationship with older Permian strata below, it would seem reasonable to conclude that an Artinskian age is probably correct and that the youngest sedimentary rocks of the Island are probably no younger than middle Early Permian in age.

SEDIMENTOLOGY

SEDIMENTARY CYCLICITY

The observed cyclicity of the Prince Edward Island redbeds can be resolved into two principal cycle types, the common fining-upwards fluvial cycle and the larger, fining-upwards megacyclic and subcyclic sequences.

Fluvial cycles, ranging up to 20 m (60 feet) in thickness, form the dominant order of vertical bedding and lateral sub-facies relationship of the redbeds. Complete cycles combining channel, levee-splay and floodplain deposits are present, as well as partial cycles in which either one of the facies units dominate.

A diagrammatic interpretation of partial and complete fluvial cycles, associated primary sedimentary structures, interpreted sub-environments of deposition and relative position with respect to a megacyclic sequence (MS.II) is given in Figure 9.

A complete fluvial cycle in which all lithofacies elements are vertically present is relatively rare; more commonly, one or more elements are missing or very thin. The resulting variations on the complete or "ideal" cycle can probably be attributed to a variety of causes, including periodic interruptions in deposition, channel abandonment and/or the limited lateral extent of individual subfacies. The fluvial cycles are themselves repeated in some general sequential order to form the larger-scale megacyclic sequences. Their fining-upward nature can, at least in part, be attributed to the distribution of partial cycles. Identifying facies in ascending order by the letters A to E, the conglomeratic base of each megacyclic sequence (A) and cross-bedded sandstone (B) occur in a repetitive succession A-B, A-B, A-B; these are channel lithofacies, interspersed locally with a transitional lithofacies C (flaggy sandstones) and levee-splay deposits D (rippled sandy siltstone).

In contrast, the relatively fine-grained top of each megacyclic sequence is dominated by repeated floodplain mudstone strata E-E-E, locally interspersed with levee-splay intercalations D, and isolated small channels B-C-D or C-D. Complete or nearly complete fluvial cycles showing channel, levee-splay and floodplain deposits A-B-C-D-E, A-B-C-D-E, A-B-C-D-E tend to be restricted to the middle part of a megacyclic sequence, though pebble and cobble conglomerates are found only near the base. Field observations suggests that an idealized approximation of the vertical arrangement of partial and complete cycles from bottom to top of a megacyclic sequence, excluding omissions, duplications and reversals of lithofacies, may read A-, A-B, A-B-C, A-B-C-D, A-B-C-D-E, B-C-D-E, C-D-E, D-E or E. Upward changes in the development of incomplete cycles only partially explain the overall fining-upwards nature of the megacyclic sequences, however: it does not fully account, for instance, for the overall gradual decrease in maximum grain-size discernable from bottom to top of each sequence. This reduction in grain size is expressed by the presence of conglomerate channel-units near the base of megacyclic sequences, whereas channel units towards the top of a sequence are not only isolated occurrences of smaller overall size, but also have medium-grained sandstone as their coarsest fraction.

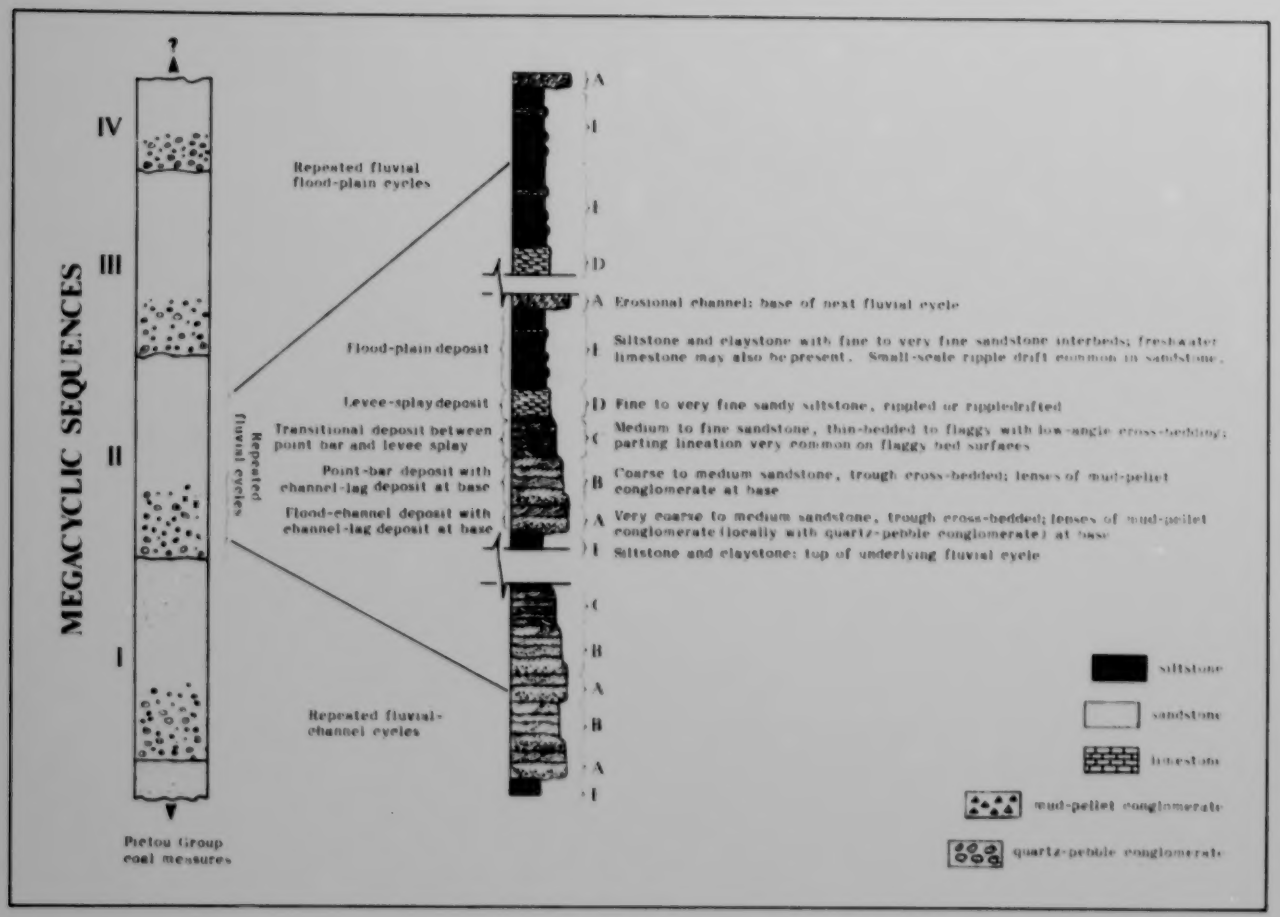


Figure 9 Diagrammatic interpretation showing idealized vertical relationships and distribution of fluvial cycles with respect to the megacyclic subdivision of the Prince Edward Island redbeds. Drawing not to scale: the megacyclic sequences are 900-1200 feet (300-400 m) thick, and complete fluvial cycles approximately 60 feet (20 m) thick.

The exact nature and origin of the megacyclic sequences in general is still uncertain. The most recent work has shown that megacyclic and subcyclic sequences, though sufficiently extensive for lithostratigraphic purposes, are nevertheless facies-bounded units that form broad lenses of conglomerate and sandstone grading laterally into finer grained flood-plain deposits of mainly siltstone and very fine sandstone. Those mapped as lithostratigraphic units in Prince Edward Island represent the most extensive fining-upward cyclic sequences that can be mapped, at present frequency of exposure, on the basis of the composition and roundness characteristics of their basal conglomerates. Other megacyclic and/or subcyclic sequences may locally be present on a smaller scale.

Megacyclic sequences are best viewed as relatively large-scale intercalations of coarse strata in a dominantly fine-grained succession though, as mapped in the field, each sequence includes both coarse and fine deposits. In terms of origin, the coarse parts could represent major meander belts of multi-story and multi-lateral channel units which periodically changed their course abruptly - in response to local imbalances in the rate of sediment accumulation on the floodplain, with or without the additional influence of periodic regional eustatic or tectonic movements.

SEDIMENTARY STRUCTURES AND SEDIMENT DISPERSAL

Trough cross-bedding is the most widely distributed primary sedimentary structure in the coarser-grained strata, mainly coarse to medium sandstone with pebble and mud-pellet conglomerates. Parting lineation and various kinds of ripples, of which ripple-drift is the most common, are only present in medium to very fine-grained silty sandstone.

Small flute, load and groove casts are also widely present in the redbeds. Significantly, the last do not occur as sole marks on the underside of beds but instead are found on the moulded surfaces of diapirs, injection lenses, lumps and pods of siltstone in sandstone. Following weathering and removal of the siltstone, the silt injection features are left as cavities in the sandstone with flute, load and (less commonly) groove casts occurring as positive forms on the cavity surfaces. The structures and their relationships to the enclosing strata in which they occur are identical to those recently described from the Boss Point Formation (Pennsylvanian) of southeastern New Brunswick (Poll and Patel 1981). Although closely resembling common sole marks, as for instance in turbidite deposits, the flute and groove casts have not formed as a result of primary sedimentary processes of scour and infilling; instead they are attributed to *rheoplasis*, a process of flow-moulding at a sharp silt-sand interface resulting from post-depositional liquefaction and sediment injection under conditions of shear. These liquefaction (quicksand) phenomena and structures, related to the associated processes of intrastratal flow and dewatering, are widely present in the redbeds.

The range of sedimentary structures observed in the redbeds can be divided into two major groups, depending on whether the structures are syn- or post-depositional in origin.

1. Those that are the result of primary sedimentary processes of transport and deposition (primary directional sedimentary structures); and

2. Structures that are related to post-depositional processes of density readjustment, intrastratal flow and dewatering of the sediments (secondary sedimentary structures).

Primary directional structures reflect current-flow directions of rivers down a paleoslope; secondary sedimentary structures, on the other hand, have no paleocurrent

significance (although their orientation could conceivably reflect the dip direction of the paleoslope under certain conditions) and merely indicate local directions of intrastratal flow during liquefaction.

Primary Directional Sedimentary Structures

Cross-bedding

Trough cross-bedding is extremely common in the redbeds, being present in all strata except very fine sandstone and siltstone. Individual cross-beds range from approximately 0.60-4.60 m (2-15 feet) in cross-sectional width, with common foreset angles of 15-22°. Medium to large-scale trough cross-bedding, the dominant structure of channel sandstone, grades laterally and upwards into smaller scale bedforms, mainly low angle (<15°) cross-bedding, ripple drift and parallel laminated (flaggy) sandstone with parting lineation. Reactivation surfaces are rare.

Sediment dispersal. The orientations of 9,963 trough cross-beds were measured in an attempt to determine the provenance of the redbeds, their dispersal patterns and the local and regional variability of transport directions (Figure 10).

Trough cross-bedding observations of individual exposures is a measure of the local direction of sediment transport and hence channel orientation. Similarly, regional compilation by vector summation provides a regional direction of sedimentary transport and, by taking into account the regional variability of dispersion of cross-bedding directions, may also provide some measure of the degree of channel meandering.

The vector mean in degrees and vector strength (in percent) for 81 compilation areas with data grouped in 30° class intervals were calculated and are shown in Figure 10. Solid black arrows indicate azimuth directions of sediment dispersal based on individual cross-bed observations amounting to between 31 and 340 in each compilation area, whereas dashed arrows refer to local compilations based on 20 observations or less.

Regional variability in cross-bedding is shown by the vector strength in percent for each compilation; the lower the vector strength percentage, the greater the variation of cross-bed orientations around the vector mean, which may relate to the degree of channel meandering. Cross-bedding variability through four class intervals (120°), for instance, has accompanying vector strengths of approximately 90%, whereas regional variability extending through eleven class intervals (330°) have accompanying vector strengths of less than 30%. The frequency distribution of class intervals is indicated in the histogram in Figure 10, and shows that the most common range extends between five and eight intervals (150°-240°). This range suggests that, insofar as cross-bedding variability is related to the degree of meandering, meander closure in these redbeds may have ranged mainly between 150° and 240°.

The vector orientations show an overall sediment dispersal pattern towards the northeast, except in the southeastern part of the Island where vector orientations indicate a more northerly trend.

The grand mean azimuth of 047° for the Prince Edward Island redbeds represents a northeasterly sediment dispersal that closely conforms to a similar transport direction in the slightly older Pictou Group in central and southern New Brunswick (cf. Poll 1973).

The more northerly transport direction of the redbeds in the southeastern coastal area of Prince Edward Island is interesting because it coincides with the presence of the

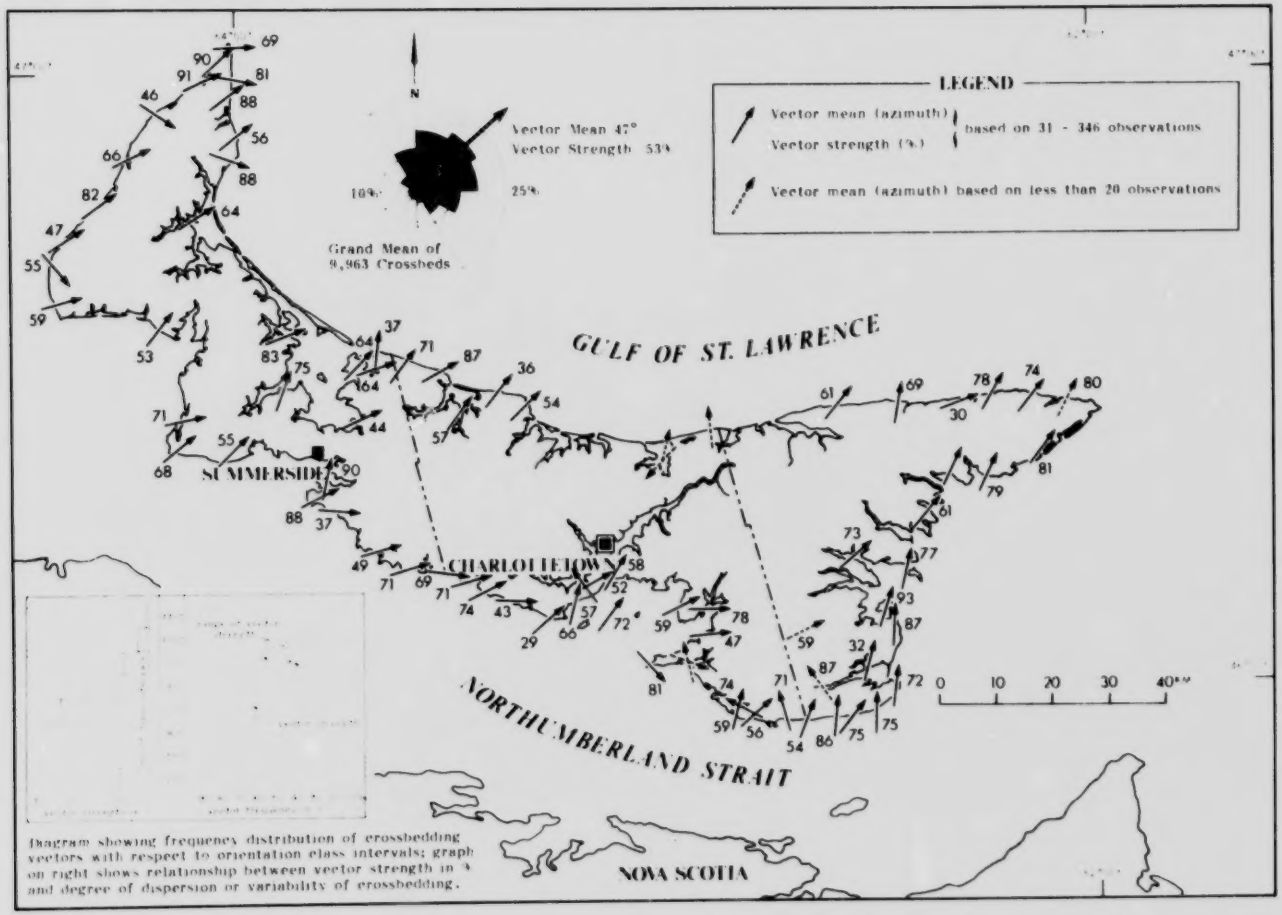


Diagram showing frequency distribution of crossbedding vectors with respect to orientation class intervals; graph on right shows relationship between vector strength in % and degree of dispersion or variability of crossbedding.

Figure 10 Sediment dispersal in Stephanian-Lower Permian strata of Prince Edward Island.

relatively immature conglomerates of Assemblage C. The lower maturity (relatively less quartz and quartzite, in combination with more "miscellaneous" pebbles) together with the characteristic low Rho values and morphology of the pebbles (blades and rollers) indicate a separate, more local source area for the conglomerates. Frankel (1966) suggested a source to the south, possibly the Highlands of Nova Scotia, because the coarsest conglomerates and thickest outcrops occur in the southeastern coastal area. He tentatively interpreted his Unit C conglomerates to represent a rapidly deposited alluvial fan with progressive growth to the north. Support for this is given by the northerly sediment dispersal pattern of Assemblage C conglomerates and associated strata along this coast. The relative abundance of poorly sorted angular to sub-angular pebbles of metamorphic and igneous origin, in combination with a southerly derivation as indicated by cross-bedding directions, suggest a nearby basement source in Nova Scotia: this may well have been the Antigonish Highlands, the Cobequid Mountains, or both. Both structures have had a long history of periodic uplift as horsts or basement highs, and are surrounded on all sides by Carboniferous strata. Their rejuvenation by uplift during late Pennsylvanian (Stephanian) time is entirely possible and would also account for the presence of soft and friable Carboniferous pebbles in the Assemblage C conglomerates.

Parting lineation

Parting lineation is a sedimentary structure consisting of sharply delineated elongate patches, ridges and furrows on bedding planes up to a few millimetres thick that show up on the flaggy surfaces of parallel-laminated sandstone, particularly when the rock is split ("parted") along the bedding. The length-to-width ratio of the features commonly ranges between 3:1 and 6:1.

The origin of parting lineation, though extensively investigated and described, is

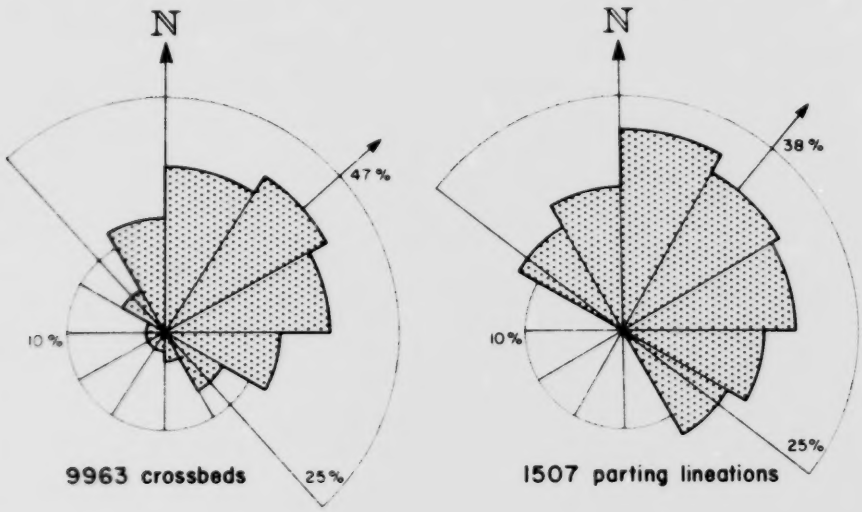


Figure 11 Rose diagrams and vector orientation of cross-bedding and parting lineation, Prince Edward Island redbeds. In the rose diagram, parting lineations are shown as one-way azimuth directions for comparison with cross-bedding, though in fact they are two-way non-azimuthal.

not certain. The preferred orientation of the elongated patches is usually thought of as current-generated, lying parallel to the direction of current flow.

Orientation. Parting lineation is a "two-way structure" whose orientation provides a line rather than an azimuth direction of sediment transport.

A total of 1,507 parting lineations were measured during the investigation. Local two-way orientations were found to vary by as much as 90°, the maximum possible, and also varied by as much with respect to local cross-bedding orientation. This variability, in particular relative to cross-bedding, is puzzling if both structures are to be interpreted as having originated from the same stream-current flow.

Notwithstanding its local variability, however, a rose diagram representing the one-way orientation of all measured parting lineations, grouped in 30° class intervals, shows a preferred northeasterly orientation that does not greatly differ to that of the cross-bedding (Figure 11).

Ripple marks

Ripple marks of various kinds, including lunate and interference marks as well as ripple-drift, are locally present in the relatively fine-grained facies of the redbeds. Of these, ripple-drift is by far the most common structure, forming sedimentation units up to 1.5 m (5 feet) thick. The angle of climb can be up to 85°. Relatively large-scale ripple-drift with a low angle of climb (<5°) was observed in places and may represent wind-blown rather than waterlain sediment.

Ripple orientations were not recorded during the present survey.

Secondary Sedimentary Structures

Structures formed from post-depositional liquefaction, sediment interflow, fluidization and dewatering of the sediments are widely present in the redbeds. Structures formed as a result of these processes show the combined effects of density instability (reverse density stratification), excessively high pore-fluid pressures, and possibly earthquake motions.

Liquefaction takes place when a sediment experiences a sudden loss of shearing resistence, associated with grain-framework collapse and rapid but temporary increase of pore-fluid pressure (Lowe 1975). At this stage a grain-supported sediment is momentarily transformed into a fluid-supported suspension (Terzaghi 1947) and is capable of flowing as a highly viscous fluid. The sediment returns to a solid state as soon as the flow stops. Liquefaction may either be induced by increasing the pore-fluid pressures from seepage of dewatering sediment below, or the sudden decrease of shearing resistence may take place as a result of spontaneous liquefaction (Terzaghi 1947); induced shear (such as earthquake shock) may cause liquefaction of porous water-saturated sediments, and the extent of liquefaction is largely dependent on the duration of induced shear (Boswell 1961). Liquified sediments settle by loading, and displace sediments of lower densities below (reverse density gradients); the latter are most commonly water-saturated clay-silt strata and, when displaced by this mechanism, will have a tendency to intrude laterally or upward as silt injection lenses and/or diapirs.

Injection phenomena of this type, as well as various dewatering features, are widespread in the Prince Edward Island redbeds, and can be subdivided into two major groups:

1. Structures reflecting sediment interflow and injection; and

2. Structures reflecting dewatering of the sediments.

Structures reflecting sediment interflow and injection are those which show evidence of post-depositional movement and injection of sediments of separate lithologies (i.e. silt in sand, sand in silt) during liquefaction. Relative movement of the sediments is primarily caused by density differences and the sediments have behaved essentially as more or less immiscible, highly viscous concentrated suspensions of restricted mobility.

Sediment interflow phenomena include finely anastomosing and dendritic networks, channels and tubes of silt in the matrix of sand and conglomerate. Sediment interflows reflect low suspensions of clay-silt in water and probably border on fluidization phenomena (Figure 12). Diapirs (Figure 13), injection lenses, lumps, pods and flakes of siltstone in sandstone (Figure 14), as well as detached sandstone beds, pseudo-nodules, convolutions, involutions and clastic injections (dykes) of sandstone in siltstone - are all examples of structures reflecting sediment injection flow. These structures occur along irregular horizons called *brecciform intervals* (Poll and Patel 1981), that extend for 100 m or more along strike. Brecciform intervals may range from a single line of amalgamation of previously liquefied sandstone beds, through relatively thin horizons with only a few flakes, pods and lumps of siltstone in sandstone (Figure 14), to intervals 3 m (10 feet) thick or more where all the aforementioned interflow and injection structures occur together in great profusion. Of interest is the common presence of flute, load and groove-like features, as well as a variety of transverse ridges and polygonal structures on the walls and/or roofs of the silt injection structures (lenses, small diapirs, lumps and pods) in these redbeds (Figures 15 and 16). Their association with structures interpreted here to be the result of sediment intrusion suggests that these features are not the result of erosion but are

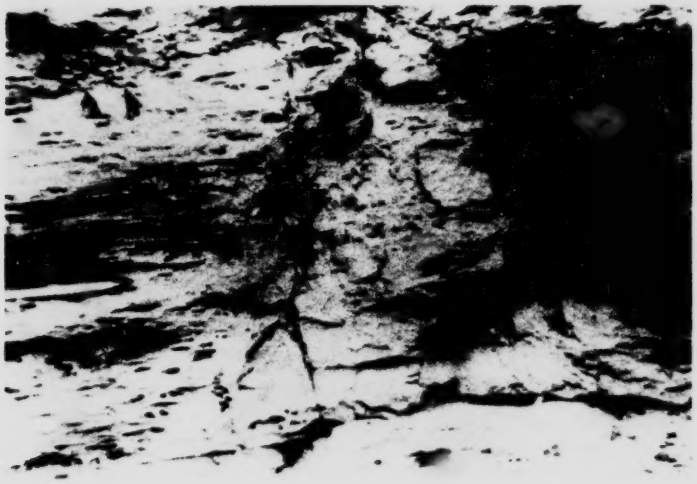


Figure 12 Sediment interflow of red clay-siltstone in sandstone along horizontal to vertical pathways. Note the brecciform interval in upper left corner of photograph and extensive obliteration of bedding in the fluidized and liquefied sections of the sandstone.

Figure 13 Siltstone diapir in sandstone. Prince Edward Island redbeds, west of Wood Islands.

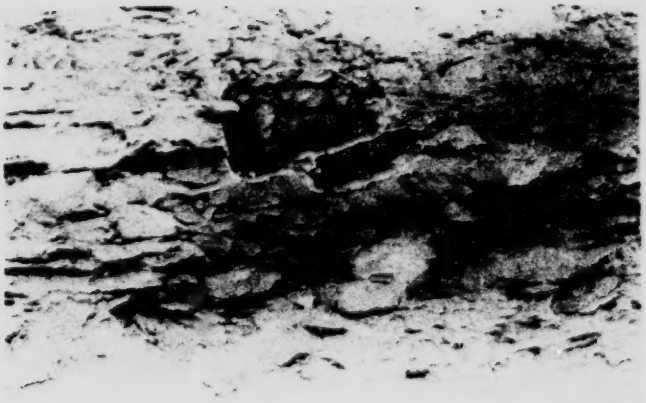


Figure 14 Brecciform interval of clay-siltstone flakes, pods and lumps in sandstone. Prince Edward Island redbeds, East Point.

related to the rheological behaviour of the sediment during liquefaction and intrastratal flow. Alternatively, some of the brecciforms and associated features may also be interpreted as having resulted from channel-margin slumping and subsequent fluting of the slump blocks by sediment-laden currents prior to rapid burial.

Structures reflecting dewatering of the sediments include clastic breccia pipes, lenses of intraformational chaotic *in situ* breccias, and intrastratal surfaces. The last-named term was introduced by Poll and Plint (1983) to describe structures seen in the Prince Edward Island redbeds that show evidence of extensive intrastratal dewatering flow during diagenesis. These do not appear to have been described previously in the geological literature.

Chaotic *in situ* breccia lenses are widely present in the redbeds, in particular in the western part of the Island. In situations of complete liquefaction the original bedding may be virtually destroyed, but locally parts of the original cross-bedded units can be found as *in situ* brecciated strata in which locally-preserved foreset laminations may still be seen (Figures 17 and 18). Clastic breccia pipes (Figure 19) locally extend upward to the base of overlying chaotic breccia lenses.

Upward migration of silty interstitial (pore) fluids through overlying sandstone can lead to an increase of clay-silt material retained in the matrix. If seepage pressures from these fluids become excessively high, dilation of the sediments can take place, and the sand will be momentarily fluidized. At this stage the sediment ceases to be grain-supported, becoming fluid-supported and cohesionless. Fluidization may take place evenly throughout the bed, or dewatering fluids may follow a number of preferred escape paths, which Lowe (1975) referred to as partial fluidization. Fluidization takes place most readily in loosely packed sediments with limited inter-particle cohesion, of sufficiently fine grain that the particles can be readily placed in suspension in the upflowing fluids (fine-to-medium sand between 0.1 mm and 0.5 mm in size). Filter-pressing of clayey/silty interstitial fluids from fine-grained sediments into overlying strata is an important mechanism by which one sediment is injected into another; this leads to a gradual reduction of the porosity and permeability of coarser grained sediments above.

As intergranular pore spaces become progressively clogged with silt and clay, escaping interstitial fluids may be forced to migrate more or less horizontally along fluidized pathways. Though on a much smaller scale, dish structures are considered to have been formed in this manner (Lowe and LoPiccolo 1974).

Laterally extensive (up to 15 m, 50 feet in size), more-or-less horizontal intrastratal surfaces are locally present in the redbeds (Figure 19), representing flow-paths of fluids from sediment dewatering. These can usually be recognized by one or more irregular hairline contact surfaces, bifurcating, subparallel, and commonly "scalloped" in form; they extend throughout sandstone units both parallel to and across bedding. Sandstone above or on either side of the contact line of the intrastratal surface invariably appears massive and featureless - even though cross-bedding foreset laminations may be conspicuous in adjacent strata. That they have served as pathways for dewatering fluids is shown by the common presence of flow markings on their contact surfaces (Figure 20).

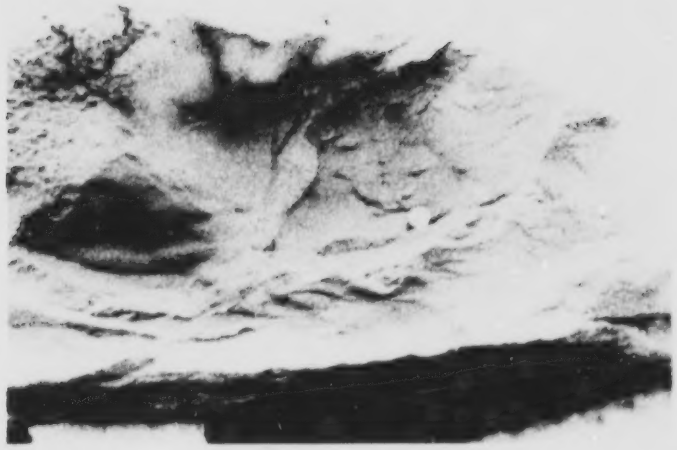


Figure 15 Flute casts on the surface of a silt-injection cavity wall: Prince Edward Island redbeds, White Sands, east of Wood Islands. Note the semi-radial pattern in the orientation of the flutes, indicating the direction of injection flow (Canadian quarter coin for scale).

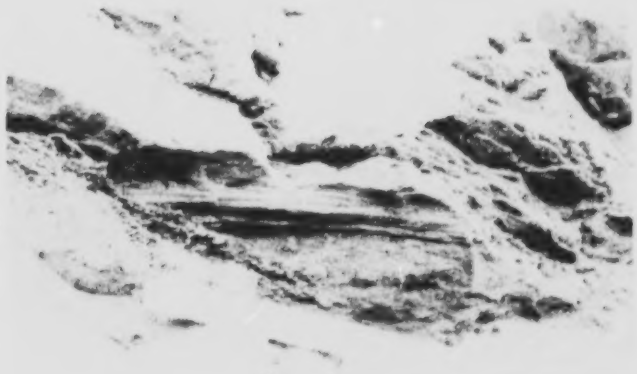


Figure 16 Partially exposed groove cast on the surface of a silt-injection cavity wall: Prince Edward Island redbeds at Point Prim.

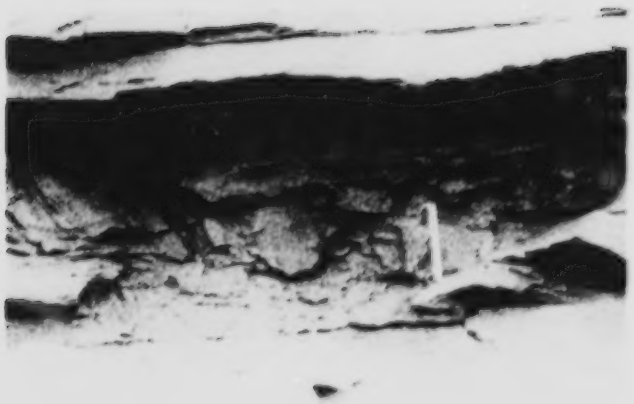


Figure 17 Relatively coarse *in situ* brecciation of sandstone that has partially overprinted original foreset bedding: Prince Edward Island redbeds, Campbellton.

Figure 18 Relatively fine *in situ* brecciation of sandstone that has largely destroyed foreset crossbed units, although the outline of trough crossbedded units are still visible: Prince Edward Island redbeds, Campbellton.

Figure 19 Clastic breccia pipe in Prince Edward Island redbeds, West Point.

Figure 20 "Scalloped" intrastratal surface in Prince Edward Island redbeds, Point Prim. Striations on the intrastratal surface resemble flow markings.

SUBSURFACE GEOLOGY

Evidence of the subsurface geology of Prince Edward Island, including offshore areas, comes from deep well drilling completed between 1910 and 1975. During this period, 22 boreholes with an aggregate footage of 39,340 m (129,062 feet) were drilled. Of these, 15 were drilled by churn or rotary rig methods and seven were diamond drill holes; 19 were drilled on land and three from drilling barges. Purposes of drilling were stratigraphic tests, exploration for oil and natural gas, coal and, to some extent, uranium and base metals.

Drilling results and borehole log summaries are presented in Figure 22 and Appendix I respectively. Borehole locations are indicated in Figure 21.

Palynological analysis of well samples shows that the surface rocks of Prince Edward Island range in age from Late Pennsylvanian (Stephanian) to approximately Artinskian (middle Early Permian) (Barss et al 1979). Pictou Group "coal measures", extending in age from Middle to Late Pennsylvanian (Westphalian C and D to Stephanian), were intersected below the Prince Edward Island redbeds in all boreholes. Coal intersections of economic significance have not been found beneath the Island, although the "coal measures" referred to within this report represent the same stratigraphic interval as that in which the Sydney, Pictou and Minto coalfield strata occur.

The grey-to-red transition in the Pictou Group, indicating the thickness of the redbeds in various parts of the Island, occurs at surface on Governor's Island in Hillsborough Bay, and ranges to a depth of approximately 900 m (3,000 feet) in the Soquip Tyrone No 1 well in Queens County. The age of the grey-to-red transition, as far as can be determined from spore data, varies from place to place, ranging from Stephanian to Early Permian, demonstrating the time-transgressive nature of the lower boundary of the redbeds.

A gradual thickening of the Pictou Group from west to east is evident. Its average thickness just west of Malpeque Bay in the Port Hill No 1, MacDougall Nos 1 and 1A, and Wellington Station No 1 wells (Figure 21) is approximately 1,250 m (4,100 feet) whereas the average thickness of the Pictou Group in the Hillsborough Bay area (Tyrone and Hillsborough Bay wells) is at least 2,705 m (8,875 feet). This thickening trend of the Pictou Group is reversed further to the east, however, where the Northumberland Strait F-25 well, situated approximately mid-way between Prince Edward Island and Cape Breton Island (No 20), shows all of the Pictou Group to be absent over the crest of a salt structure at shallow depth (the Northumberland Strait Dome, Shaw 1974); the well penetrated rocks of the Canso Group (Namurian) at the sea floor, and drilled to basement at 3,000 m (9,850 feet).

A major disconformity at the base of the Pictou Group is evident from drilling results. This disconformity is represented by an erosional or non-depositional hiatus in the stratigraphy that apparently extended from probable Westphalian A to early Westphalian C time (Riversdale to lower Pictou Group) in Hillsborough Bay No 1 well to late Visean-early Namurian (Windsor-Canso Groups) in the MacDougall 1 and 1A, Wellington Station, Irishtown and East Point wells (Figure 22).

Canso-Riversdale strata are interpreted to be present in Green Gables No 1 and Tyrone No 1 and possibly also the Hillsborough Bay well (Hacquebard 1972, Barss et al. 1979).

Windsor Group evaporites were intersected in all deeper wells (i.e. MacDougall 1 and 1A, Wellington Station, Irishtown, Green Gables, Tyrone, Hillsborough Bay and Northumberland Strait F-25), at varying depths ranging between 366 m and 4,167 m (1,200-13,670 feet). The evaporites occur both as intercalations and interbeds of silty or impure anhydrite in siltstone, to thick massive interbeds, pillows and domes of salt.

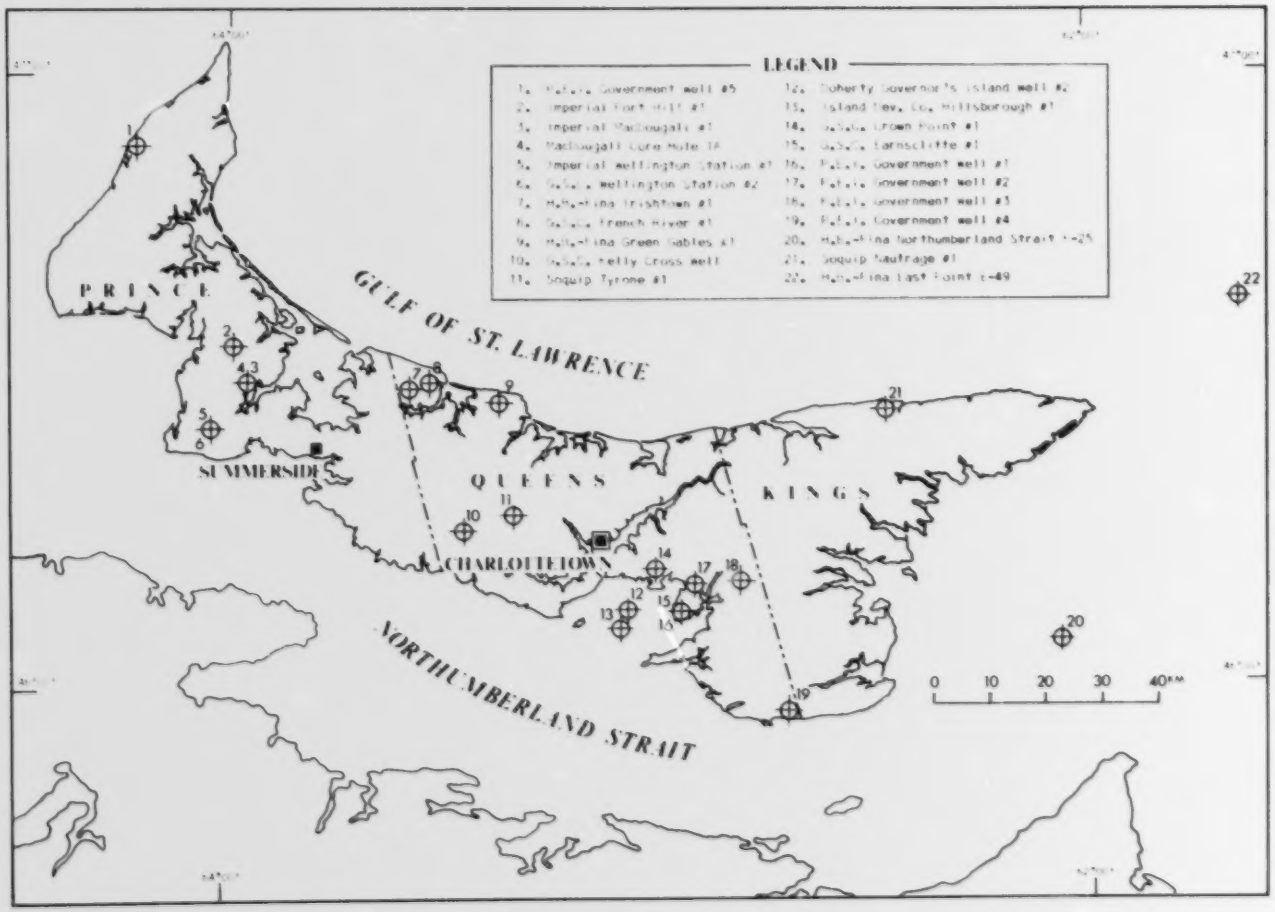


Figure 21 Bore hole location map of Prince Edward Island.

Strata of presumed Horton or Horton-Windsor age, consisting mainly of conglomerate, arkosic sandstone, shale and locally interbedded mafic volcanic rocks, were intersected only in the lower part of the Irishtown and Northumberland Strait F-25 wells but may possibly also be present in the MacDougall and Wellington Station wells. The latter two intersected mainly fine-grained siltstone with evaporite interbeds and mafic volcanic rocks. The presence of the volcanic rocks may be taken to suggest a Horton age, whereas the evaporites with siltstone, on the other hand, suggest a Windsor age. Furthermore, the volcanic rocks in the Wellington Station well could also be a diabase dyke or sill, similar to the Middle Triassic sill exposed at the northeastern corner of George Island, 26 km (16 miles) northeast of Wellington Station. It is suggested here that the lowermost strata in the Wellington Station well should be considered to be of Windsor age until such time that a more definite age has been obtained for the volcanic rocks and/or enclosing strata.

The coarse conglomeratic nature of presumed Horton-age strata, together with the thick intercalations of mafic volcanic rocks, may indicate only limited potential at depth beneath the Island for oil shale or oil-bearing strata, similar to those of the Albert Formation of New Brunswick. It should be borne in mind, however, that the apparent Horton age for the coarse conglomerate below the Windsor evaporites has not been confirmed, and that coarse conglomerate and mafic volcanic rocks can also occur within the Windsor Group - as indeed they do elsewhere in New Brunswick and Cape Breton Island. Finally, the extension of the oil-and gas-bearing Albert shale of New Brunswick may continue at depth in the southern part of the Northumberland Strait, between Nova Scotia and Prince Edward Island, rather than further north beneath the northern part of the Island itself.

Relatively thick intercalations of mafic volcanic rocks, 100 m (300 feet) or more thick, occur within Horton or Horton-Windsor strata of the Wellington Station, Irishtown and Northumberland Strait F-25 wells.

Granitic basement was intersected at a relatively shallow depth of 1,408 m (4,620 feet) in the Port Hill well in western Prince Edward Island, and also occurs at a depth of 2,950 m (8,680 feet) in the Northumberland Strait F-25 well east of the Island. Both wells may have been drilled on basement highs; the Port Hill well probably intersected a northeasterly subsurface extension of the fault-bounded Kingston Uplift of New Brunswick. A similar northerly subsurface extension of the Antigonish Highlands of Nova Scotia may have been intersected by the F-25 well.

STRUCTURAL GEOLOGY

Prince Edward Island is underlain by a series of shallow-dipping strata tilted to the northwest, northeast and southeast. Several salt-cored anticlines are known to be present.

Inspection of dip distributions show a close relationship between bedrock structure and the physiography of the Island, which consists of a series of low-angle cuestas. From west to east, a number of physiographic and structural relationships are apparent, as described below.

Structure

Western part of the Island

The north-northeastern elongation of the Island west of Cascumpec Bay in Prince County is controlled by the northerly strike of the strata and shallow but persistent easterly dips in the range 1-3°. This strike direction is not only reflected in the older Pictou beds in central and northern New Brunswick but also trends parallel to the basal

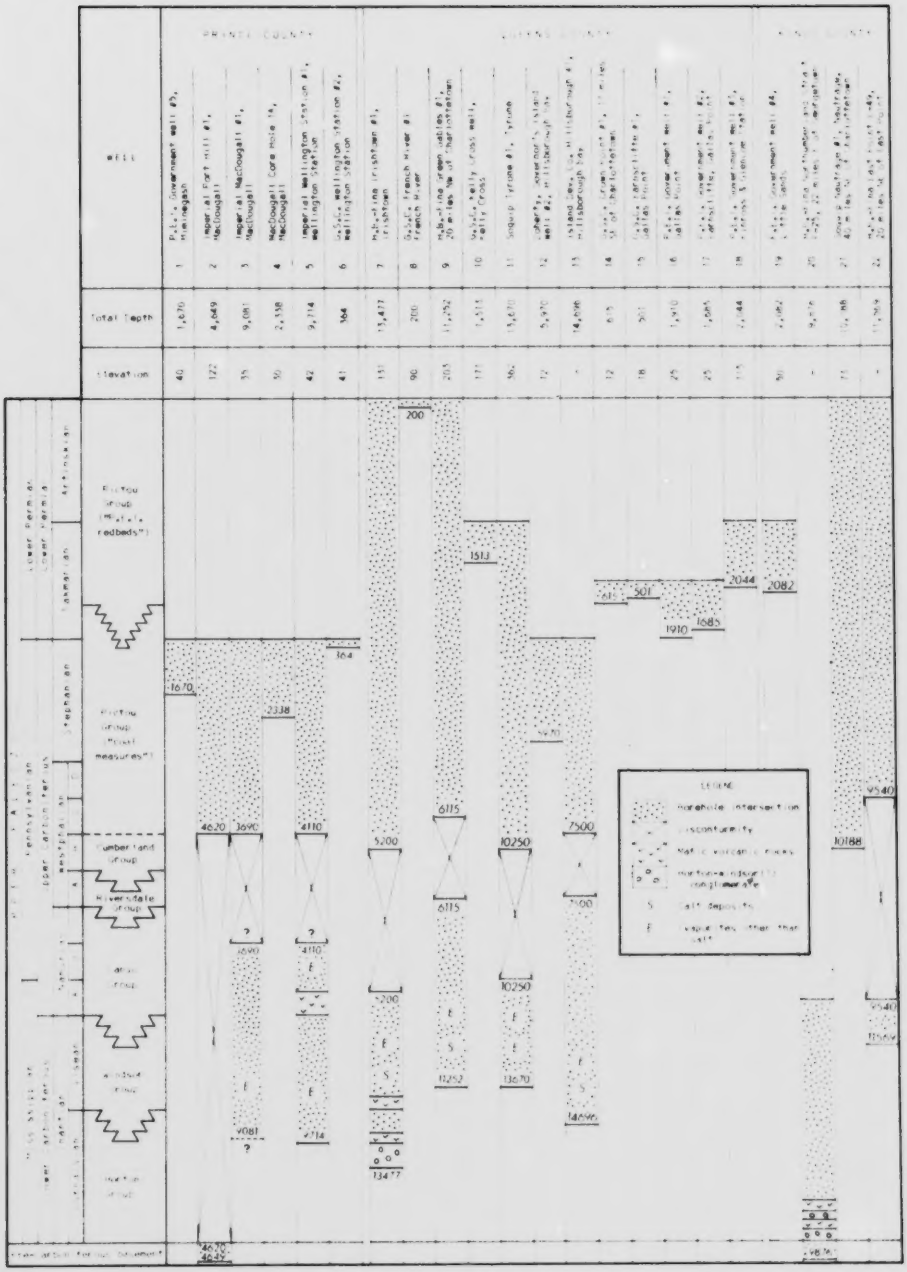


Figure 22 Synopsis of borehole intersections of Prince Edward Island.

Pictou/pre-Carboniferous unconformable contact in that area. The regional strike and dip of the strata can be attributed to slight post-depositional tilting of major basement blocks which gave a passive regional tilt to the strata prior to being exposed to erosion (Poll 1970, 1973).

Lowland areas centred on Egmont Bay

The area around Egmont Bay in western Prince County shows an open anticlinal flexure plunging to the northeast at a shallow angle. This anticlinal structure coincides with the subsurface extension of the so-called Kingston Uplift of New Brunswick; the latter is made up of deformed Carboniferous and other rocks, and comprises a narrow northeasterly trending thrust-belt bringing basement rocks up to a shallow depth below the surface near Moncton, New Brunswick. Its northeasterly extension into Prince Edward Island has previously been suggested from gravity data (Garland 1953), from drilling results (Howie and Cumming 1963) and from magnetic data (Bhattacharyya and Raychaudhuri 1967). Several major high-angle thrust faults, of which the Belleisle Bay and Petitcodiac Faults are the best well known, bound the Kingston Uplift. The Belleisle Bay Fault in New Brunswick can be traced along strike southwestward into Maine and apparently also in the opposite direction to the northern shore of Egmont Bay. Surface evidence of either fault has not been observed, however, and it is suggested here that the fault is confined to depth becoming either insignificant or extinct towards the surface. The northeasterly extension of the Kingston Uplift is evidently reflected by the low-amplitude anticlinal flexure centred on Egmont Bay rather than by fault displacement.

Lowland areas of central Prince County centred on Malpeque and Bedeque Bays

Structurally and stratigraphically this is one of the least well understood areas of the Island. The low-lying shore affords poor exposures and, where bedding attitudes have been measured, the results provide conflicting data. Observations most commonly indicate horizontal or shallow dip angles to either the northeast or southwest, suggesting horizontal to gently undulating bedding attitudes on northwesterly trending axes.

The matter is further complicated by the observation that the beds on the western and eastern shore of Bedeque Bay appear dissimilar and that the basal quartz-pebble conglomerates at Seacow and Graham Heads have as yet not been traced along strike into the western shore of Bedeque Bay. More extensive outcrop or drilling in the area is required to ascertain the stratigraphic relationships of the rocks in the western part of the Island to those in the central part.

South-central areas of the Island (eastern Prince and western Queens Counties)

The region between Bedeque and Hillsborough Bay is generally characterized by gentle northeasterly to northerly dips. The gentle northerly dip of the strata west of Victoria may reflect tilting along the northern flank of the Tormentine Dome, which is believed to lie to the south at depth, beneath the Northumberland Strait. The presence of this dome was suggested by Shaw (1974) on seismic evidence, with an estimated depth to the top of salt of approximately 2,133 m (7,000 feet). Dips in the area between Canoe Cove and Rice Point, west of Charlottetown, show a rapid change in direction from southwesterly through westerly to northwesterly. This change reflects a subsidiary westerly plunging anticline centred on Nine-Mile Creek, just north of Rice Point, on the northwestern flank of the much larger salt-cored Gallas Point Anticline centred on Hillsborough Bay.

Hillsborough Bay area

Hillsborough Bay lies in a northeasterly plunging breached anticline, named Gallas Point Anticline by Dawson and Herrington (1871), that is underlain by a salt dome or pillow

trending east-northeast. The Hillsborough Bay well, just to the south of Governor's Island, intersected massive salt between 4,020 and 4,270 m (13,200-14,000 feet). The presence of a salt pillow at depth is reflected at the surface by strata dipping northwest and north at an average of 7° along the western shore of Hillsborough Bay, with similar dip angles to the east and southeast along the eastern shore of the bay. The salt pillow underlying the Gallas Point Anticline appears to lie on strike with two salt domes in southeastern New Brunswick, one near Sackville and another at Dorchester. The Hillsborough Dome, therefore, may be interpreted as forming part of a salt-cored anticlinal structure trending between northeast and east from southeastern New Brunswick, through southeastern Prince Edward Island into the eastern part of Northumberland Strait.

An interpreted fault associated with the Hillsborough Dome has been tentatively projected to the northeast through Pownal Bay. Its presence is based on rapid changes in strike and dip of the strata between Rice Point and St Peters Island, and again on opposite shores of Pownal Bay.

North-central part of the Island

Bedding attitudes on the shallow-dipping redbeds of Prince Edward Island are seldom discernable with any reasonable degree of confidence in the absence of continuous coastal sections; as a result, the regional structure has to be corroborated by lithostratigraphic evidence. On this basis, the central part of the Island appears underlain by a gently north-northeasterly trending synclinal flexure separating the Egmont Bay anticlinal flexure to the west and the Gallas Point Anticline (Hillsborough Dome) to the southeast. This trend is locally complicated, however, by the presence of at least one and possibly two salt domes or pillows, centred on Cape Tryon and Cavendish Capes respectively. The local anticlinal or domal nature of the strata is best revealed along the shore on both sides of Cape Tryon where a maximum dip of 3° to the northwest and 12° to the southeast are encountered. The presence of salt below Cape Tryon has been confirmed by the Irishtown well, which intersected salt at a depth between 1,915 and 2,541 m (6,283-8,338 feet).

The domal structure is less well pronounced at Cavendish Capes. Very gentle northwesterly and southeasterly dips are discernable in the high cliffs at Orby Head which appear to be formed by a shallow anticlinal structure striking to the northeast. The presence of salt at depth below Cavendish Capes has been confirmed by the Green Gables well, drilled approximately 5 km (3 miles) west-southwest of Orby Head, which intersected salt 9 m (30 feet) above its final depth of 3,430 m (11,250 feet).

Northeastern part of the Island

The area east of Tracadie Bay, extending to East Point and the town of Souris in northern Kings County, shows very shallow northerly dips of 1-2°. The gentle tilt of the beds can best be seen along the coast section southeast of East Point.

The region is generally low-lying with an extensive cover of glacial material. The glacial cover is usually 1-3 m (3-10 feet) thick and locally may be in excess of 14 m (45 feet) (Crowl 1969). Consequently, inland exposures are very scarce except for a few minor rock pits.

Southeastern part of the Island

The area lying to the south of Souris and east of Hillsborough Bay is dominated by the northeasterly trending Kilmuir Syncline. The latter, which appears as a doubly plunging structure is, in reality, not a true syncline but rather a relatively flat-lying intervening zone surrounded by salt-cored anticlines.

The salt is of Windsor (Mississippian) age, and has flowed laterally to form a number of pillows and/or domes. The exact date that lateral flow and doming of the salt commenced is not known but, inasmuch as it affected Lower Permian strata, the timing would have to be at least post-Early Permian.

The locations of the domes have previously been delineated by Shaw (1974) who also calculated estimated depths to the top of salt. This was derived from a seismic isochron map between a horizon mapped within the volcanic rocks (i.e. below the salt) and a horizon identified as the top of the Windsor evaporites. It was assumed that anomalous thicknesses of this section were due to salt flowage into domes (Shaw 1974, p. 35). From west to northeast, the surface anticlines mapped by Frankel (1966) and associated salt domes at depth named by Shaw (1974) are as follows: *Gallas Point Anticline*, comprising the Hillsborough Dome centred on Hillsborough Bay, measured top of salt 3,927 m (12,885 feet) in the Hillsborough Bay well; *Wood Islands Anticline*, comprising the Cape Cliff and Cape John Domes, where the top of the salt was estimated at approximately 3,350 m (11,005 feet). The Wood Islands Anticline is almost on strike to the west with the east-west salt-cored Malagash-Minudie Anticline on the north coast of Nova Scotia extending into New Brunswick. On strike to the northeast, the Wood Islands Anticline contains two main domes, namely the Murray Head Dome, with an estimated top of salt at 1,370 m (4,500 feet), and the Northumberland Strait Dome; the measured top of salt of the latter dome is 1,375 m (4,510 feet) in Northumberland Strait F-25. The change in strike and prevailing low-angle westerly dips at Murray Head, and all along the south-eastern coast of the Island north of Murray Harbour, probably represent the western flank of the Murray Head Dome.

Finally, the low-angle westerly plunging anticline and associated change in dip directions from southwesterly to northerly, centred on Howe Bay, south of the town of Souris, may be the westerly limits of yet another dome beneath the eastern part of Northumberland Strait. However, no seismic evidence has been presented for the presence of a salt dome in this area; the gently folded strata centred on Howe Bay may alternatively be a northerly extension of the Murray Head-Northumberland Strait Domes, or be an on-strike extension of the Hillsborough Dome, or both.

The axial zone of the Kilmuir Syncline comprises an outlier of MS.IV, mainly resistant hill-forming thick-bedded coarse conglomerate (Assemblage A).

Faults

Only a few minor faults have been observed, all with an apparent stratigraphic separation in the order of 10 m (30 feet) or less. They vary in strike between east-northeast and southeast, and occur at Red Rock on the southeastern shore of Egmont Bay, near Rice Point west of Charlottetown, and just west of Orby Head in northern Queens County.

The interpreted fault through Hillsborough Bay has been described on p. 39 and is based on sharp changes in strike and dip between Rice Point and St Peters Island, and on the opposite shores of Pownal Bay. A fault in this area has also been suggested from seismic evidence by Shaw (1974).

Several large faults are believed to extend at depth from New Brunswick to the northeast into the Egmont Bay area (Figure 1, frontispiece). As has previously been mentioned in this report, no surface evidence for these faults has been found. Faults mapped in the Egmont Bay area are all of small displacement.

A major fault is believed to have been intersected by the Irishtown well at a depth

of 1,502 m (4,928 feet) below sea level. Down to that depth, the well log reports strong westerly dips, changing over a short distance to strong northerly dips below.

Joints

Vertical to steeply dipping joints, with inclinations greater than 75°, are widespread throughout the Island. The orientation of the joints is displayed in three rose diagrams (Figure 23). The prevailing joint directions are essentially east-northeasterly and subparallel to the two main structural trends (i.e. east and northeast) of the Carboniferous rocks of the Maritime region.

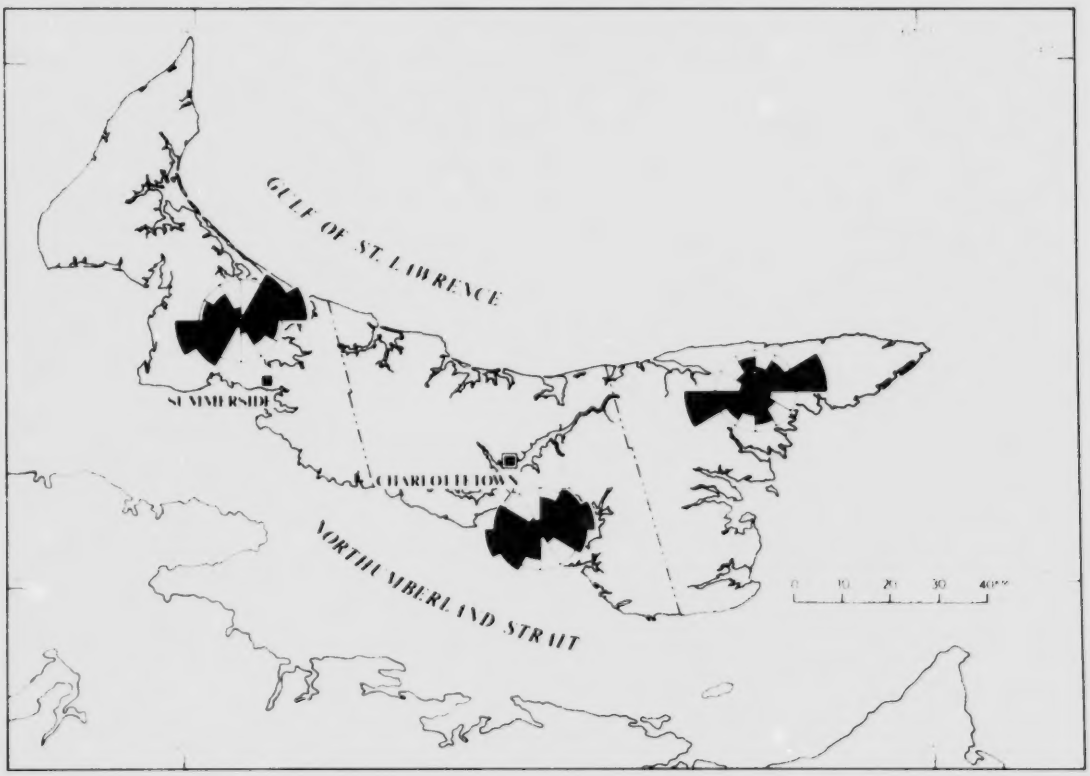


Figure 23 Rose diagrams showing the orientation of joints in the western, southern and northeastern part of Prince Edward Island.

ECONOMIC GEOLOGY

The mineral resource potential of Prince Edward Island centres on two widely different mineral commodities: uranium and gravel. Salt, and associated products such as potash or the storage of liquified natural gas (LNG) in salt domes, can at present only be considered as remote possibilities because of the considerable depth at which the salt occurs beneath the Island (see also Figure 22, p. 36).

Uranium

Uranium was first reported in black patches and dark centres of greyish-green reduction zones and spheroids in the redbeds of the west coast of the Island. Subsequent scintillometer and analytical work on surface exposures and borehole samples by the Geological Survey of Canada in 1968 not only revealed anomalous radioactivity in many of the greenish-grey phases of the redbeds, but also detected a widespread presence of weakly radioactive strata in the subsurface rocks of the Island. The best results were obtained from a six-inch core sample of the Kelly Cross well from a depth of 760.5 feet (231 m) which analysed 290 ppm U_3O_8 (Prest et al. 1969). Follow-up work by H.E. Dunsmore of the Geological Survey of Canada in 1977 demonstrated the presence of uranium-vanadium mineralization in surface rocks at a number of new localities in western, southwestern and south-central parts of the Island. Assay results from this survey ranged between 10.5 ppm and 259 ppm U_3O_8 (Dunsmore, 1977).

One object of the present survey was to determine the stratigraphy and regional continuity of mineralized and potentially mineralized sections. For this purpose a McPhar YC-33A scintillometer was utilized throughout the investigation, not only to confirm previous work, but also to determine the preferred mode of uranium occurrence and the nature of the host strata. Up to 15 double scintillometer readings were recorded as standard procedure at each individual outcrop or coastal section. The purpose of the "double" readings was to compare each radioactivity count of the greyish-green "reduced" interbeds with nearby red "oxidized" strata. In the majority of observations it was found that background readings in the range of 75-125 cps characterized the redbeds, whereas the greyish-green and grey interbeds invariably showed higher readings ranging between 1.1 to 5 times background. The majority of readings obtained in this type of comparative work may be regarded as "background"; these are left as blank areas on Map 2 (in pocket), whereas better-than-background or possibly anomalous readings have been calculated and designated by separate symbols with levels of 2-3, 3-4 and 4-5 times background.

Readings with 2-3 times background have only regional significance and, as such, identify regions of possible uranium potential without necessarily determining immediate target areas for more concentrated follow-up work. Based on the distribution pattern of 2-3 times background readings, five areas with possible uranium potential may be identified as follows (Map 2):

1. The western part of the Island from North Point to West Point
2. The Hillsborough Bay area
3. Orby Head
4. Cape Bear - Murray Head; and
5. The North Lake area.

Readings of 3-4 times background may be of more local significance than the previous group. They may perhaps fall within the range of readings that were identified by previous

workers as being anomalous (Prest et al. 1969) and could represent assays possibly up to 250 ppm U_3O_8. Areas with readings between 3-4 times background include (Map 2):

6. The northwestern part of the Island from just south of North Point to West Point
7. Just west of Percival Bay (Egmont Bay)
8. Along the coast south of Murray River
9. On the northeastern shore of Rollo Bay, Souris
10. The northwestern shore area of Darnley Basin, just east of Malpeque Bay.

Readings of 4-5 times background are the most significant and represent the highest scintillometer readings obtained from the Island. Areas from where readings of 4-5 times background were obtained may warrant more concentrated follow-up work on the exposure or stratum from which the readings were obtained. Only five outcrops with readings in excess of 4 times background have been identified during the course of the present survey; four on the west coast of the Island, and one on Hillsborough Bay (Map 2):

11. Skinner's Pond, 16 km southwest of North Point
12. Miminegash
13. Burton, 16 km southwest of Miminegash
14. Cape Wolfe
15. Rice Point, 14 km southwest of Charlottetown.

The Miminegash occurrence is probably the same as the site of the original discovery by the Geological Survey of Canada (Prest 1969) whereas the other occurrences, in particular at Rice Point, constitute new discoveries.

The best scintillometer readings were consistently found in association with greyish-green reduction zones, within the redbeds along the base of fluvial channels overlying orange-red very fine-grained sandstone and siltstone. The channel sandstone units show extensive scouring at the base into underlying strata, are made up of one or more mud-pellet conglomerate units and/or coarse to medium sandstone, and commonly contain carbonate cement. The highest readings appear confined to the base of the basal greyish-green zone within the channel units creating the impression that colour, reflecting the state of iron oxidation rather than lithology, is of prime significance as a guide to mineralization.

The radioactive minerals responsible for the anomalous readings are invariably associated with greyish-green and grey strata rather than redbeds; however, not all grey beds or zones within the redbeds are necessarily anomalous. On the contrary, it was found that the majority of grey beds were not anomalous (1.1 times background) or, at best, showed only slightly elevated readings (1.7 times background).

Mineralized reduction patches and spheroids are locally present in fine sandy siltstone. Mineralization can be detected by the presence of black cores up to 12 mm ($\frac{1}{2}$ inch) in diameter within reduction spheroids up to 10 cm (4 inches) (Figure 24) and by similarly black but irregularly distributed patches up to 20 cm (8 inches) along lamination surfaces. This is the type of occurrence that is said to have originally led to the discovery of uranium-vanadium mineralization in the Prince Edward Island redbeds.

Uranium in the black centre of reduction spheroids is not necessarily present in each occurrence, however. A microprobe analysis of the dark centre of a reduction sphere from rocks just north of Miminegash Pond showed only the presence of vanadium, and the mineral

vanoxite ($V_4+4V_2+5O_{13}.8H_2O$?) is possibly the only one present in the dark core. Significantly, uranium was not detected (J.E. Tilsley, personal communication, 1978).

Not all reduction spheroids contain black cores. Barren reduction spheroids were observed in a number of localities, notably Holland Cove and Keppoch (Poll 1978). Reduction spheroids lacking uranium reportedly also occur in the MacDougall 1A bore hole (Howie 1977).

Initial work by the Geological Survey of Canada on the dark cores and patches of two samples from the Miminegash area revealed the presence of 420 ppm and 750 ppm U_3O_8 and associated vanadium of 5.0% and 3.29% respectively. A soft yellowish mineral commonly present in the dark patches was tentatively identified by X-ray diffraction pattern as rauvite ($CaO.2UO_2.5V_2O_5.16H_2O$), whereas a similar soft but greenish-yellow mineral has been interpreted from its X-ray diffraction pattern as francevillite ($Ba.Pb.2UO_2.2VO_4.5H_2O$). Although the nature of the black patches has not been ascertained, the mineral doloresite ($3V_2O_4.4H_2O$) has been tentatively identified as one of the constituents of the black matrix (Prest et al. 1969).

Integration of scintillometer data with the regional stratigraphy of the Island shows that the best potential host beds for uranium are mainly confined to MS.I, SS.IA and MS.II. It may be significant that these sequences are also characterized by, or closely overlain by, strata containing widespread evidence of plant fossils and of either penecontemporaneous rhyolite extrusion or provenance from rhyolite terrain. It is quite possible that these two factors combined have been of major influence in the supply of the uranium (weathering and leaching of the rhyolite) and its initial concentration in the sedimentary environment around plant remains (locally reducing conditions). Subsequent oxidation of the plant remains in the redbed environment may have led to secondary leaching of the uranium mineralization by groundwater and re-concentration at the impervious interface between siltstone and coarse sandstone at the base of fluvial channel sequences.

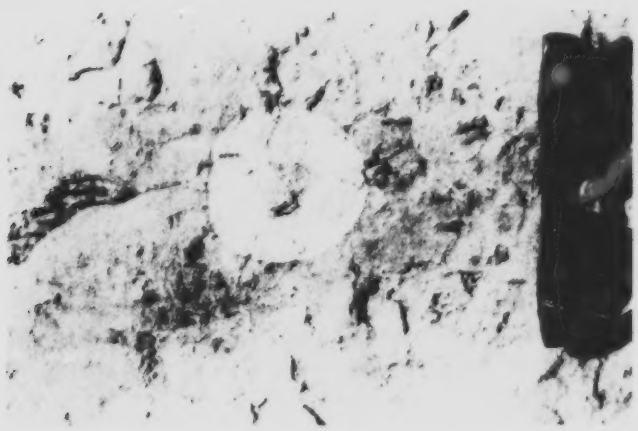


Figure 24 Mineralized reduction spheroid containing possible vanadium and uranium in the dark core.

More specifically, the best scintillometer readings appear preferentially associated with strata in which both channel and overbank sequences occur in alternating vertical succession. For reasons that are at present poorly understood it was found that the contact between channel sandstone above and siltstone below may have had some significance in the concentration of radioactive minerals. This is in contrast to basal channel sandstone units overlying other sandstone units (i.e. multi-story channel units) which appear invariably unmineralized. This observation is potentially of importance as it suggests that the search for uranium occurrences may be restricted to areas that are underlain by complete or nearly complete fluvial cycles ("A-B-C-D-E" and "B-C-D-E") in which both channel ("A-B-C") as well as overbank ("D-E") components are represented. Considering the nature of channel units, any associated mineralized beds would constitute one or several vertically repeated occurrences with an areal extent limited to that of the channel units.

The only other sub-environment in which the rapid vertical change from siltstone to channel sandstone is markedly developed is at the base of each megacyclic sequence. It is in this sub-environment that particular attention should be paid to the presence of uranium, as the potential lateral extent of the favourable bedded units in the form of the basal mud-pellet and quartz-pebble conglomerate with coarse sandstone is very considerable.

Further work is required to elucidate the source and origin of the uranium-vanadium mineralization. Nevertheless, the following observations may be of significance with respect to the genesis of the uranium minerals:

1. Uranium is primarily confined to megacyclic sequences in which:
   a) evidence of plant remains in the form of fossil fern imprints and plant stems are widespread; and
   b) evidence of prior rhyolite extrusion is suggested by the presence of anomalously high concentrations of rhyolite pebbles in the basal conglomerates of MS.II and MS.III.

2. It may also be remarked that mineralized beds along the west coast, at Cape Egmont, around the perimeter of Hillsborough Bay, at Rice Point, along the northern coast just east of Cape Tryon, at Cavendish Capes, Cape Bear and Rollo Bay all occur on the flanks of broad anticlinal and synclinal structures.

Gravel

The conglomerate horizons of MS.IV, exposed at or near the surface in the central part of the Kilmuir Syncline, were previously evaluated for their potential as gravel sources by Foster (1969). He concluded that, although the occurrences were spotty, large deposits of low quality gravel still existed in the area.

The present survey has greatly extended the evaluation of gravel potential within the province. Conglomerate lenses, as gravel sources, were recognized as being essentially confined to lithostratigraphic horizons; consequently the areas in which gravel might be found at or near the surface have been enlarged.

The present stratigraphic interpretation suggests that gravel may be found along broad belts representing the bases of MS.II, MS.III and MS.IV. This is supported by the presence of a number of known gravel pits and quarries that are "on strike" along conglomerate horizons. Being generally an erosion-resistant rock, the conglomerate commonly underlies flat-topped hills and ridges standing up to 10 m or so above the surrounding area.

Well-known gravel quarries at the base of MS.II include the Piusville, Mount Royal, West Devon, Freeland, and Tyne Valley pits; at the base of MS.III are the Gambles Corner and Westmoreland Pits; whereas at the base of MS.IV are the Hope River, Springton, Bedford Station, Bayfield and the Iona-Brooklyn Pits.

In assessing the potential for gravel in the areas between known pits, it should be borne in mind that although the presence of extra-basinal pebbles will identify the lithostratigraphic unit as a conglomerate or conglomeratic sandstone, their mere presence does not necessarily guarantee an adequate supply of gravel for commercial purposes. An additional restrictive factor in obtaining gravel from these conglomerate units is the degree of carbonate cementation of the matrix: carbonate-cemented conglomerate is relatively hard and resistant, and requires extensive disintegration before a workable gravel can be obtained. De-cementation of conglomerate by natural processes has apparently occurred in a number of places, however, locally yielding workable deposits to a depth of 3-4.5 m (10-15 feet).

The best potential gravel area within bedrock conglomerate lies in the axial region of the Kilmuir Syncline, in the southeastern part of the Island; the whole area is underlain by a major conglomerate unit comprising the base of MS.IV. Gravel has already been obtained from a number of pits, several of which are undoubtedly capable of extending their reserves and expanding operations should the need arise. Lack of good inland exposures unfortunately precluded more detailed work on the gravel potential of the Island without the aid of excavating or drilling equipment.

SUMMARY AND CONCLUSIONS

The redbeds of Prince Edward Island are entirely continental in origin and have been tentatively subdivided into four major fining-upward cyclic sequences. Informally designated Megacyclic Sequences I-IV, each sequence has a status equivalent to formation with respect to lateral continuity, contact relationships with overlying and underlying strata, and lithological criteria. Megacyclic Sequences I and III have locally been subdivided into smaller-scale Subcyclic Sequences IA and IIIA, equivalent in status to members.

Each megacyclic sequence consists of conglomerate, sandstone and siltstone beds, approximately 300-400 m (900-1,200 feet) thick in total, and representing a succession of partial-to-complete fluvial cycles up to 20 m (60 feet) thick. Subcyclic sequences are 60-90 m (200-300 feet) thick and are likewise made up of partial to complete fluvial cycles. They are not as coarse at the base as megacyclic sequences, and lack thick-bedded and coarse conglomerate units.

Calcareous intraformational mud-clast breccias, pebble and cobble conglomerates and coarse sandstones are widely present at the base of the megacyclic sequences whereas the top of each unit is made up of finer grained lithofacies, mainly fine sandstone and siltstone.

The conglomerates consist mainly of quartz and quartzite pebbles, except those of MS.II and MS.III which are characterized by an anomalously high rhyolite content (25-45%). The source of the rhyolite pebbles is not known but can only be interpreted in general terms from the available data. The prevailing northeasterly direction of sediment dispersal in Pictou Group strata in both New Brunswick and Prince Edward Island indicates the rhyolite source to have been from the southwest, perhaps in southern New Brunswick, or even the New England states.

The megacyclic sequences are themselves made up of fining-upwards fluvial cycles consisting of a coarse mud-pellet conglomerate at the base, passing up through coarse to medium cross-bedded sandstone and ripple-drifted fine sandstone to thinly laminated or massive siltstone at the top. "Top-truncated" fluvial cycles are present towards the base of each megacyclic sequence, whereas fully developed and preserved fluvial cycles characterize the transition from bottom to top.

Despite the red colour of the strata, MS.I (including SS.1A) of Stephanian age is characterized by the common presence of Carboniferous coal measures-type fossil-fern imprints. In contrast, fossil plant stems rather than fern imprints are locally present in MS.II (Stephanian-Early Permian age), whereas no fossil evidence, except for fucoid-like trace fossils, worm borings and ferruginized root tubes, has been observed in MS.III and MS.IV (Early Permian).

Based on paleontological and palynological evidence, the age of the Prince Edward Island redbeds ranges from Upper Pennsylvanian (Stephanian) to perhaps as young as middle Early Permian (Artinskian).

Structurally, the redbeds are mainly tilted towards the northeast (ranging from southeast to northwest) at an average 1-3° dip so that the oldest redbeds are exposed in the southern and western part and the youngest strata in the northeastern part of the Island. An exception is the axial zone of the Kilmuir Syncline in the southeast where extensive basal conglomerates are exposed in an outlier of MS.IV.

Local changes in strike and dip (maximum observed is 12°) can be attributed to the effects of salt tectonics at depth beneath the Island and to local tilting and uplift of a basement horst extending to the northeast from New Brunswick into Prince Edward Island. The observed deformation of the redbeds, though mild in comparison with some older Carboniferous strata in New Brunswick and Nova Scotia, suggests that probably the Alleghenian Orogeny in eastern Canada did not take place until at least late Early Permian time.

The generally low degree of induration and gently dipping nature of the Prince Edward Island redbeds indicate that structural deformation has been minor. The average 1-3° northeasterly dip of the strata conforms with that of the Pictou Group of New Brunswick which has previously been attributed to the slight northeasterly tilting of large faultbounded basement rocks. One such tilt-block, the so-called Kingston Uplift of New Brunswick, has also mildly affected the redbeds around Egmont Bay. Salt tectonics have played a role in minor tilting of the strata around Hillsborough Bay, Cape Tryon, Cape Bear and possibly at Cavendish Capes and Howe Bay.

The subsurface geology includes igneous and metasedimentary basement rocks, angular unconformably overlain by probable Horton Group red conglomerate, arkosic sandstone and shale with intercalations of mafic volcanic rocks and Windsor Group evaporites and red shale, all of Mississippian age. The latter sequence is separated from overlying Pennsylvanian strata by a major stratigraphic break that almost everywhere beneath the Island extended from early Namurian to late Westphalian C (Canso-Riversdale and Cumberland Groups).

The Pennsylvanian succession below the redbeds, though apparently lacking coal of economic significance, includes coal measures of the same stratigraphic interval that contains the Sydney, Pictou and Minto coal fields of Nova Scotia and New Brunswick.

Two types of uranium-vanadium mineralization have been recognized: that associated with green reduction zones at the base of channel sandstone sequences, and mineralized dark

cores of reduction spheroids in orange-red sandy siltstone. The hydrous uranium vanadate minerals rauvite and francevillite were previously identified from dark cores and irregular patches within grey reduction spheroids and zones in red sandy siltstone. No mineralization has as yet been detected to account for the apparent uranium concentrations at the base of fluvial channel sequences, and neither source nor origin of the uranium mineralization is known. The best uranium occurrences detected so far appear concentrated in MS.I and MS.II.

Two separate environments for uranium mineralization may be considered in the selection of exploration targets:

1. Greenish-grey reduction zones at the base of individual fluvial cycles, overlying siltstone. Associated deposits, if present, would tend to be ribbon-like in surface extent, according to the channel morphology. They would tend to be relatively restricted in size in comparison with the second type.

2. Green reduction zones at the base of megacyclic sequences. Associated mineral deposits, if present, could have a potential for very large scale low-grade deposits.

Mineralized reduction spheroids in fine grained sandy siltstone are not thought to offer potential for economic deposits.

The Island may have a better potential for gravel than was previously suspected. Widespread quartz-pebble conglomerates at the base of MS.II, MS.III and MS.IV may constitute local sources of gravel. There are, however, three inhibiting factors to be considered in the economic benefication of the conglomerates: the patchy and discontinuous nature of individual conglomerate beds, and the degree of carbonate cementation of the conglomerates, rendering the strata hard and difficult to disaggregate, and the poor quality of the gravel so produced.

BIBLIOGRAPHY

Bain, F.
1881: Note on fossils from the Red Sandstone system of Prince Edward Island: Canadian Naturalist, v. 9, p. 463-464.

Barss, M.S., Bujak, J.P., and Williams, G.L.
1979: Palynological zonation and correlation of sixty seven wells, Eastern Canada: Geol. Surv. Canada, Paper 78-24, p. 1-9.

Barss, M.S., Hacquebard, P.A., and Howie, R.D.
1963: Palynology and stratigraphy of some Upper Pennsylvanian and Permian rocks of the Maritime Provinces: Geol. Surv. Canada, Paper 63-3.

Barss, M.S. and Hacquebard, P.A.
1967: Age and the stratigraphy of the Pictou Group in the Maritime Provinces as revealed by fossil spores: Geol. Assoc. Canada, Spec. Paper No 4, p. 267-283.

Bell, W.A.
1938: Fossil flora of Sydney Coalfield, Nova Scotia: Geol. Surv. Canada, Memoir 215, 334p.

Bhattacharyya, B.K. and Raychaudhuri, B.
1967: Aeromagnetic and geological interpretation of a section of the Appalachian belt in Canada: Can. J. Earth Sci., v. 4, p. 1015-1037.

Boswell, P.G.H.
1961: Muddy sediments: some geotechnical studies for geologists, engineers and soil scientists: Heffers & Sons Ltd, Cambridge.

Brandon, L.L.
1966: Groundwater hydrology and water supply of Prince Edward Island: Geol. Surv. Canada Paper 64-38.

Case, E.E.
1905: *Bathygnathus borealis* Leidy, and the Permian of Prince Edward Island: Science, v. 22, p. 52-53.

Copeland, M.J.
1957: The arthropod fauna of the Upper Carboniferous rocks of the Maritime Provinces: Geol. Surv. Canada, Memoir 286.

Crowl, G.H.
1960a: Surficial geology, Mount Stewart, Prince Edward Island: Geol. Surv. Canada, Map 36-1960.

1960b: Surficial geology, Souris, Prince Edward Island: Geol. Surv. Canada, Map 37-1960.

1969: Geology of the Mount Stewart-Souris map area, Prince Edward Island: Geol. Surv. Canada, Paper 67-66.

Crowl, G.H. and Frankel, L.
1970: Surficial geology of Rustico map area, Prince Edward Island: Geol. Surv. Canada Paper 70-39.

Darrah, W.C.
1936: Permian elements in the fossil flora of the Appalachian Province: II. *Walchia*: Harvard Univ. Bot. Mus. Leaflets, v. 4, p. 9-19.

Dawson, J.W.
1842: Notes on the geological excursion in a part of Queens County, Prince Edward Island: Royal Gazette, Charlottetown, v. 12, p. 4.

1848: On the New Red Sandstone of Nova Scotia: Quart. J. Geol. Soc. London, v. 4, p. 50-59.

1855: Acadian Geology, an account of the geological structure and mineral resources of Nova Scotia: Edinburgh, 388p.

1874: On the upper coal formation of eastern Nova Scotia and Prince Edward Island in its relation to the Permian: Quart. J. Geol. Soc. Lond., v. 30, p. 209-219.

1878: Supplement to the Second Edition of Acadian Geology: MacMillan & Co. Ltd., London 102p.

1891: The geology of Nova Scotia, New Brunswick and Prince Edward Island, or Acadian Geology: MacMillan & Co. Ltd., London, 694p.

Dawson, J.W., and Herrington, B.J.
1871: Report on the geological structure and mineral resources of Prince Edward Island: John Lovell, Montreal, 51p.

Dunsmore, H.E.
1977: Uranium resources of the Permo-Carboniferous Basin, Atlantic Canada: Report of Activities, Part B: Geol. Surv. Canada, Paper 77-18, p. 341-347.

Elias, M.K.
1936: Late Paleozoic plants of the mid continent region as indicators of time and environment: Proc., 16th Intl. Geol. Congr. v. 1, p. 691-700.

Ells, R.W.
1883: Geological map of Prince Edward Island: Geol. Surv. Canada, Rept. Progr.

1885: Report on explorations and surveys in the interior of the Gaspe Peninsula: Geol. and Nat. Hist. Surv. of Canada, Report Program 1882-83-84, Part E (section on Prince Edward Island, p. 11E-19E).

Foster, H.D.
1969: Alternate sources of gravel for Prince Edward Island: a preliminary review of physical and economic factors: unpubl. rept., Policy and Planning Branch, Canada Department of Energy, Mines and Resources.

Frankel, L.
1960: Surficial geology, Montague map area: Geol. Surv. Canada, Map 33-1900.

1966: Geology of southeastern Prince Edward Island: Geol. Surv. Canada, Bull. 145.

Frankel, L. and Crowl, G.H.
1970: Permo-Carboniferous stratigraphy and structure of Central Prince Edward Island: Geol. Surv. Canada, Paper 69-17.

Garland, G.D.
1953: Gravity measurements in the Maritime Provinces: Dominion Observatory Publ. 16.

Gesner, A.
1846: Report of the Geological Survey of Prince Edward Island (Report to H.V. Huntley, Lieutenant Governor), Appendix D, Cornwallis, N.S.

Gussow, W.C.
1953: Carboniferous stratigraphy and structural geology of New Brunswick, Canada: Bull. Am. Assoc. Pet. Geol., v. 37, p. 1713-1816.

Hacquebard, P.A.
1972: The Carboniferous of eastern Canada: Compt. Rend. 7th Intl. Congr. Carboniferous Stratigraphy and Geology, p. 69-90.

Holden, R.
1913: Some fossil plants from Eastern Canada: Ann. Bot. v. 27, p. 243-255.

Howie, R.D.
1977: Geological studies and evaluation of MacDougall Core Well 1A, western Prince Edward Island: Geol. Surv. Canada, Paper 77-20.

Howie, R.D. and Barss, M.S.
1974: Upper Paleozoic rocks of the Atlantic Provinces, Gulf of St Lawrence and adjacent continental shelf. Offshore geology of eastern Canada: Geol. Surv. Canada, Paper 74-30, v. 2, p. 35-50.

1975: Paleogeography and sedimentation in the Upper Paleozoic, eastern Canada: in: Canada's Continental Margins and Offshore Petroleum Exploration: edited by C.J. Yorath, E.R. Parker and D.J. Glass: Can. Soc. Pet. Geol., Mem. 4, p. 45-58.

Howie, R.D. and Cumming, L.M.
1963: Basement features of the Canadian Appalachians: Geol. Surv. Canada, Bull. 89.

Huene, F. von
1905: *Pelycosaurier im Deutschen Muschelkalk*: Neues Jahrb. Mineral., Biel.-Bd. 20, p. 321-353.

Ingall, E.D.
1909: Borings on Prince Edward Island: Geol. Surv. Canada, Sum. Rept. 1909.

Langston, W., Jr.
1963: Fossil vertebrates and the late Palaeozoic redbeds of Prince Edward Island: Nat. Mus. Canada, Bull. 187.

LeGallais, C.J.
1983: Stratigraphy, sedimentation and basin evolution of the Pictou Group (Pennsylvanian), Oromocto Sub-Basin, New Brunswick, Canada: unpubl. MSc thesis, McGill University, 123p.

Leidy, J.
1854: On *Bathygnathus borealis*, an extinct Saurian of the New Red Sandstone of Prince Edward Island: J. Acad. Nat. Sci. Philadelphia, v. II, p. 327-330.

Lowe, D.R.
1975: Water escape structures in coarse grained sediments: Sedimentology, v. 22, p. 157-204.

Lowe, D.R. and LoPiccolo, R.D.
1974: The characteristics and origins of dish and pillar structures: J. Sed. Pet., v. 44, p. 484-501.

Milligan, G.C.
1949: Geological survey of Prince Edward Island: rept., Department of Industry and Natural Resources, Province of Prince Edward Island.

Poll, H.W. van de
1970: Stratigraphical and sedimentological aspects of Pennsyvanian strata in southern New Brunswick: unpubl. Ph.D. Thesis, University of Wales.

1973: Stratigraphy, sediment dispersal and facies analysis of the Pennsylvanian Pictou Group in New Brunswick: Mar. Sed., v. 9, p. 72-77.

1978: Bedrock geology and uranium distribution of central and western Prince Edward Island: Rept., Dept. Industry and Commerce, Prince Edward Island.

Poll, H.W. van de, and Patel, I.M.
1981: Flute casts and related structures on moulded silt injection surfaces in continental sandstone of the Boss Point Formation, southeastern New Brunswick, Canada: Mar. Sed. Atl. Geol. v. 17, p. 1-22.

Poll, H.W. van de, and Plint, A.G.
1983: Secondary sedimentary structures associated with fluidization zones in Permo-Carboniferous redbeds of Prince Edward Island, Canada: Mar. Sed. Atl. Geol., in press.

Prest, V.K.
1962: Geology of Tignish map-area, Prince County, Prince Edward Island: Geol. Surv. Canada, Paper 61-28.

1964: Geology of Charlottetown map-area, Prince Edward Island: Geol. Surv. Canada, Paper 64-16.

1972: Geology of Malpeque-Summerside area, Prince Edward Island: Geol. Surv. Canada, Paper 71-45.

1973: Surficial deposits of Prince Edward Island: Geol. Surv. Canada, Map 1366A.

Prest, V.K. and Brady, J.G.
1964: The geology and ceramic properties of shale from Beacon Point, Prince Edward Island: Geol. Surv. Canada, Paper 63-35.

Prest, V.K., Steacy, H.R. and Bottrill, T.J.
1969: Occurrences of uranium and vanadium in Prince Edward Island: Geol. Surv. Canada, Paper 68-74.

Sames, C.W.
1966: Morphometric data of some recent pebble associations and their application to ancient deposits: J. Sed. Pet., v. 36, p. 126-142.

Shaw, W.S.
1974: Geology and mineral resources of Prince Edward Island: unpubl. rept., Dept. Industry and Commerce, Prince Edward Island.

Terzaghi, K.
1947: Shear characteristics of quicksand and soft clay: Proc. 7th Texas Conf. Soil Mech. and Found. Engr.

Wanless, R.K., Stevens, R.D., Lachance, G.R. and Delabio, R.N.
1973: Age determinations and geological studies, K-Ar isotopic ages, Rept. II: Geol. Surv. Canada, Paper 73-2.

Appendix 1

SUMMARIES OF BORE HOLE LOGS

PRINCE EDWARD ISLAND

1. Prince Edward Island Government Well No 5 56
2. Imperial Port Hill No 1 56
3. Imperial McDougall No 1 57
4. Geological Survey of Canada - Prince Edward Island Government MacDougall Core Hole No 1A 57
5. Imperial Wellington Station No 1 58
6. Geological Survey of Canada Wellington Station No 2 58
7. Hudson's Bay - Fina et al. Irishtown No 1 59
8. Geological Survey of Canada French River No 1 59
9. Hudson's Bay - Fina Green Gables No 1 60
10. Geological Survey of Canada Kelly Cross Well No 1 60
11. Soquip et al. Tyrone No 1 61
12. Henry L. Doherty: Doherty (Governor's Island) Well No 2 61
13. Island Development Corporation Hillsborough No 1 62
14. Geological Survey of Canada Crown Point No 1 62
15. Geological Survey of Canada Earnscliffe No 1 63
16. Prince Edward Island Government Well No 1 63
17. Prince Edward Island Government Well No 2 64
18. Prince Edward Island Government Well No 3 64
19. Prince Edward Island Government Well No 4 64
20. Hudson's Bay - Fina Northumberland Strait F-25 65
21. Soquip et al. Naufrage No 1 66
22. Hudson's Bay - Fina East Point E-49 66

1. **Prince Edward Island Government Well No 5** Drilled: 1910

Stratigraphic and coal drilling, churn drill.
At Miminigash, Prince County.

Elevation: approximately 12 m (40 feet).
Total depth: 509 m (1,670 feet).

0-222.5 m (0-730 feet)	Pictou Group: P.E.I. redbeds, bright red shale and sandy shale.
222.5-323.1 m (730-1,060 feet)	Transition sequence: redbeds to "coal measures": grey sandstone, bright red shale and sandy shale.
323.1-509.0 m (1,060-1,670 feet)	Pictou Group "coal measures" sequence: grey sandstone, grey and brown shale; traces of coaly material.

2. **Imperial Port Hill No 1** Drilled: 1958

Test well, rotary rig.
At 1.2 km ($\frac{3}{4}$ mile) west of Port Hill, Prince County.

Elevation: 37.2 m (122 feet).
Total depth: 1417 m (4,649 feet).
Log submitted by Imperial Oil Limited.

0-445.0 m (0-1,460 feet)	Pictou Group: P.E.I. redbeds, brownish red sandstone and bright red shale.	
445.0-579.1 m (1,460-1,900 feet)	Transition sequence: "coal measures", to redbeds, grey and reddish brown sandstone, red shale.	
579.1-1,408.2 m (1,900-4,620 feet)	Pictou Group "coal measures": grey sandstone, grey and red shale, coaly material.	
Interval	518.2-1,234.4 m (1,700-4,050 feet)	ranges from Westphalian to Stephanian in age (Barss et al., 1963).
---------- non-conformity ----------		
1,408.2-1,417.0 m (4,620-4,649 feet)	Granitic basement.	

3. **Imperial McDougall No 1** Drilled: 1958

Test well, rotary rig.
2 miles northwest of MacDougall, Prince County.

Elevation: 10.7 m (35 feet).
Total depth: 2,767.9 m (9,081 feet).
Log submitted by Imperial Oil Limited.

0-420.6 m (0-1,380 feet)	Pictou Group: P.E.I. redbeds, brownish-red sandstone and red shale.	
420.6-563.9 m (1,380-1,850 feet)	Pictou Group: Transition sequence, "coal measures to redbeds", grey and reddish brown sandstone, red and grey shale.	
563.9-1124.7 m (1,850-3,690 feet)	Pictou Group "coal measures": grey sandstone, grey, reddish-brown and red shale, coaly fragments.	
Interval	30.5-1,082.0 m (100-3,550 feet)	ranges from Westphalian C to Stephanian in age (Barss et al., 1963).
---------- disconformity ----------		
1124.7-2767.9 m (3,690-9.081 feet)	Pre-Pictou strata: may be Riversdale, Canso, Windsor and Horton Groups (?). Mainly chocolate brown to greenish-grey shale; minor polymictic conglomerate at top (Canso equivalent?).	
	2,008.6-2,362.2 m (6,590-7,750 feet)	Anhydrite in grey brown and chocolate coloured shales (of Windsor age?).

4. **Geological Survey of Canada - Prince Edward Island Government** Drilled: 1975
MacDougall Core Hole No 1A

Coal, uranium, vanadium and base metal evaluation test boring, diamond drill-hole.
At approximate 105 m (345 feet) southeast of Imperial MacDougall No 1.
Village of MacDougall, Prince County.

Elevation: approximately 9 m (30 feet).
Total depth: 712.6 m (2,338 feet).
Log submitted by R.D. Howie.

0-387.1 m (0-1,270 feet)	Pictou Group: P.E.I. redbeds, red to greyish red and brownish red sandstone; calcareous mudstone breccia, siltstone and claystone.	
387.1-424.0 m (1,270-1,391 feet)	Pictou Group: Transition zone, "coal measures" to redbeds, grey and reddish-brown to red sandstone and siltstone.	
424.0-712.6 m (1,391-2,338 feet)	Pictou Group "coal measures": mainly grey sandstone, claystone breccia, siltstone and claystone. Carbonaceous partings present throughout section.	
At	551.4 m (1,809 feet)	age of strata is Stephanian (Howie, 1977).

5. **Imperial Wellington Station No 1** Drilled: 1958

Test well, rotary rig.
At 3.2 km (2 miles) southwest of Wellington, Prince County.

Elevation: 12.8 m (42 feet).
Total depth: 2,960.8 m (9,714 feet).
Log submitted by Imperial Oil Limited.

0-478.5 m (0-1,570 feet)	Pictou Group: P.E.I. redbeds, mainly medium to coarse grained sandstone - bright red shale.	
478.5-740.7 m (1,570-2,430 feet)	Pictou Group: Transition sequence, "coal measures" to redbeds, grey and red sandstone and shale, minor coaly fragments.	
740.7-1,252.7 m (2,430-4,110 feet)	Pictou Group "coal measures": grey sandstone, minor conglomerate, grey and red shale, pyrite and coaly fragments.	
Interval	500.0-1150.6 m (1,640-3,775 feet)	age of strata range from Westphalian C to Stephanian (Barss et al., 1963).
---------- disconformity ----------		
1,252.7-1,468.2 m (4,110-4,817 feet)	Pre-Pictou strata: mainly Canso (?) or Windsor Group, red shale, minor white limestone, red sandstone, anhydrite evaporites.	
1,468.2-1,764.8 m (4,817-5,790 feet)	Horton-Windsor Groups (?), mainly mafic volcanic rocks with interbedded arkosic sandstone-conglomerate.	
1,764.8-2,960.8 m (5,790-9,714 feet)	Mainly reddish brown-chocolate brown and grey shale, minor sandstone.	
Interval	2,100.1-2,744.7 m (6,890-9,005 feet)	interbedde anhydrite and salt; may be Windsor, or perhaps Horton?

6. **Geological Survey of Canada Wellington Station No 2** Drilled: 1962

Stratigraphic test hole - Diamond Drill Hole No 1.
At Wellington Station, 17.7 km (11 miles) west of Summerside.

Elevation: 12.5 m (41 feet).
Total depth: 110.9 m (364 feet).
Log submitted by R.D. Howie.

0.0-110.9 m (0-364 feet)	Pictou Group: P.E.I. redbeds, red sandstone, siltstone and claystone.

7. Hudson's Bay - Fina et al. Irishtown No 1 Drilled: 1972

Test well, rotary rig.
Near Irishtown, approximately 19 km (12 miles) northeast of Summerside, Queens County.

Elevation: 40 m (131 feet) above sea level.
Total depth: 4,107.8 m (13,477 feet).
Log submitted by Hudson's Bay Oil and Gas Co Limited.

0-792.5 m (0-2,600 feet)	Pictou Group: P.E.I. redbeds, sandstone and shale.	
792.5-865.6 m (2,600-2,840 feet)	Pictou Group: Transition sequence, "coal measures" to redbeds; brownish-red and grey sandstone and shale.	
Interval	819.9-826.0 m (2,690-2,710 feet)	is of Early Permian (Sakmarian) age (Barss et al., 1979).
865.6-1,585.0 m (2,840-5,200 feet)	Pictou Group, "coal measures", mainly grey sandstone, grey and reddish brown shale. This interval ranges between late Westphalian B and Stephanian in age (Barss et al., 1979).	
---------- disconformity ----------		
1,585.0-4,107.8 m (5,200-13,477 feet)	Pre-Pictou strata: mainly Windsor and Horton Groups present.	
1,915.1-2,541.4 m (6,283-8,338 feet)	Windsor salt, limestone, minor red shale, anhydrite and arkose.	
2,541.4-3,026.7 m (8,338-9,930 feet)	Mafic volcanic rocks, grey-brown sandstone, conglomerate and shale.	
3,026.7-4,107.8 m (9,930-13,477 feet)	Shale, mafic volcanic rocks, reddish-grey sandstone, becoming conglomeratic towards base.	
Interval	1,603.2-1,902.0 m (5,260-6,240 feet)	ranges between late Visean-early Namurian in age (Barss et al., 1979).

8. Geological Survey of Canada French River No 1 Drilled: 1962

At the Village of French River, 24 km (15 miles) northeast of Summerside, Queens County.

Elevation: 27.4 m (90 feet).
Total depth: 61.0 m (200 feet).
Log submitted by R.D. Howie.

0-61.0 m (0-200 feet)	Pictou Group: P.E.I. redbeds, red sandstone, siltstone and claystone.

9. **Hudson's Bay - Pina Green Gables No 1** Drilled: 1972

Test well, rotary rig.
Near Rustico Harbour, approximately 32 km (20 miles) northwest of Charlottetown, Queens County.

Elevation: 61.9 m (203 feet).
Total depth: 3,429.6 m (11,252 feet).
Log submitted by Hudson's Bay Oil and Gas Co Limited.

0-853.4 m (0-2,800 feet)	Pictou Group: P.E.I. redbeds, mainly red sandstone and siltstone.	
853.4-1,876.0 m (2,800-6,155 feet)	Pictou Group "coal measures": grey sandstone, grey, greyish-green and reddish-brown shale, coaly fragments common. This interval ranges in age from Westphalian (C?) to Stephanian (Barss et al., 1979).	
---------- disconformity ----------		
1,876.0-3,429.6 m (6,155-11,252 feet)	Pre-Pictou strata: mainly Canso-Riversdale and Windsor Groups present.	
1,876.0-2,966.9 m (6,155-9,734 feet)	Canso-Riversdale Groups: grey sandstone and red brown shale, coaly fragments common at top.	
Interval	2,304.3-2,359.1 m (7,560-7,740 feet)	is late Namurian in age (Barss et al., 1979).
2,966.9-3,420.5 m (9,734-11,222 feet)	Windsor Group: grey and grey-green shale, minor anhydrite.	
3,420.5-3,429.6 m (11,222-11,252 feet)	Windsor Group: salt.	
Interval	3,112.0-3,383.3 m (10,210-11,100 feet)	is late Visean, possibly early Namurian in age (Barss et al., 1979).

10. **Geological Survey of Canada Kelly Cross Well No 1** Drilled: 1964

Stratigraphic test, diamond drillhole.
At Village of Kelly Cross, approximately 23 km (14 miles) west of Charlottetown, Queens County.

Elevation: 52.1 m (171 feet).
Total depth: 461.1 m (1,513 feet).
Log submitted by R.D. Howie.

0-461.1 m (0-1,513 feet)	Pictou Group: P.E.I. redbeds, red sandstone, siltstone and claystone, conglomerate near top of hole.

11. **Soquip et al. Tyrone No 1** Drilled: 1975

Test well, rotary rig.
At the Village of Tyrone, approximately 21 km (13 miles) west of Charlottetown, Queens County.

Elevation: 110.3 m (362 feet).
Total depth: 4,166.6 m (13,670 feet).
Log submitted by Soquip et al.

0-941.8 m (0-3,090 feet)	Pictou Group: P.E.I. redbeds, red sandstone and siltstone.
941.8-3,124.2 m (3,090-10,250 feet)	Pictou Group "coal measures": grey sandstone, grey, greyish-green and reddish-brown siltstone, coaly material, minor conglomerate.
Interval 1,307.6-3,124.2 m (4,290-10,250 feet)	ranges in age from late Westphalian B to Stephanian (Barss et al., 1979).
---------- disconformity ----------	
3,124.2-4,166.6 m (10,250-13,670 feet)	Pre-Pictou strata: mainly Canso and Windsor Groups; major break between Canso and Pictou (Riversdale and Cumberland apparently absent).
3,124.2-3,901.4 m (10,250-12,800 feet)	Canso Group, dark brown to greyish-brown sandstone, and siltstone becoming coarse and conglomeratic towards base; very minor limestone.
Interval 3,148.6-3,843.5 m (10,330-12,610 feet)	ranges in age from late Visean to early Namurian.
3,901.4-4,157.5 m (12,800-13,640 feet)	Windsor Group: conglomerate, silty limestone, oolite, sandstone, anhydritic sandstone.
4,157.5-4,166.6 m (13,640-13,670 feet)	Windsor Group: evaporites, mainly anhydrite.

12. **Henry L. Doherty: Doherty (Governor's Island) Well No 2** Drilled: 1926(?)

Test well.
On northwest corner of Governor's Island, Hillsborough Bay, Queens County.

Elevation: approximately 3.6 m (12 feet).
Total depth: 1,819.7 m (5,970 feet).
Log submitted by Borings Division, Geological Survey of Canada.

0-1,819.7 m (0-5,970 feet)	Pictou Group: Transition sequence and "coal measures"; grey, red and brown-red sandstone and shale, coalified plant remains common below 1,344.2 m (4,410 feet).

13. **Island Development Corporation Hillsborough No 1** Drilled: 1944

Test well, rotary rig.
At 2,209 m (7,250 feet) south 57° west of Governor's Island, Hillsborough Bay, Queens County.

Elevation: sea level.
Total depth: 4,479.3 m (14,696 feet).
Log submitted by D.C. Maddox.

0-213.4 m (0-700 feet)	Pictou Group: Transition sequence, "coal measures" to redbeds, grey and greyish brown sandstone, reddish grey to reddish brown shale.
213.4-2,286.0(?) m (700-7,500(?) feet)	Pictou Group "coal measures": grey sandstone, grey, greenish-grey and reddish-brown siltstone.

Interval between approximately 400-2133 m (1,300-7,000 feet) ranges in age from Westphalian C to Stephanian (Hacquebard, 1972).

---------- disconformity ----------

2,286.0(?)-4,479.3 m (7,500(?)-14,696 feet)	Pre-Pictou strata: Riversdale ? Canso and Windsor Groups present.
2,286.0(?)-3,749.0 m (7,500(?)-12,300 feet)	mainly Canso-Riversdale(?) reddish-brown, chocolate brown and grey shale minor sandstone, few coalified plant remains.
3,749.0-4,023.4 m (12,300-13,200 feet)	Windsor Group: reddish-brown shale and anhydrite.
4,023.4-4,479.3 m (13,200-14,696 feet)	Windsor evaporites, salt and anhydrite.

14. **Geological Survey of Canada Crown Point No 1** Drilled: 1962

On Crown Point Road, 11 km (7 miles) southeast of Charlottetown.

Elevation: 3.8 m (12 feet).
Total depth: 186.8 m (613 feet).
Log submitted by R.D. Howie.

0-186.8 m (0-613 feet)	Pictou Group: P.E.I. redbeds, red, reddish-grey and reddish-brown sandstone, siltstone and claystone.

15. Geological Survey of Canada Earnscliffe No 1 Drilled: 1962

Stratigraphic test - Diamond Drill Hole No 3.
At Gallas Point, 18 km (11 miles) southeast of Charlottetown, Queens County.

Elevation: 5.5 m (18 feet).
Total depth: 152.7 m (501 feet).
Log submitted by R.D. Howie.

0-152.7 m (0-501 feet)	Pictou Group: Transition sequence "coal measures" to redbeds, red, greyish brown, grey and greenish grey sandstone, siltstone, claystone and claystone breccia	
Interval	101.2-106.7 m (332-350 feet)	contains thin coaly partings and is of Sakmarian (Early Permian) age (Barss et al., 1963).

16. Prince Edward Island Government Well No 1 Drilled: 1910

Stratigraphic and coal drilling test - churn drill.
At Gallas Point, 18 km (11 miles) southeast of Charlottetown, Queens County.

Elevation: approximately 8 m (25 feet).
Total depth: 582.2 m (1,910 feet).
Log submitted by I.D. Ingall.

0-576.1 m (0-1,890 feet)	Pictou Group: Transition sequence "coal measures" to redbeds. Grey brown, reddish brown sandstone and shale, minor grey calcareous sandstone and grey shale
576.1-582.2 m (1,890-1,910 feet)	Pictou "coal measures": coarse grey sandstone and brownish-grey shaly sandstone.

17. **Prince Edward Island Government Well No 2** Drilled: 1910

Stratigraphic and coal drilling test, churn drill.
At 4 km (2½ miles) northeast of Earnscliffe, Gallas Point, Queens County

Elevation: approximately 8 m (25 feet).
Total depth: 513.6 m (1,685 feet).
Log submitted by I.D. Ingall.

0-513.6 m (0-1,685 feet)	Pictou Group: Transition sequence "coal measures" to redbeds. Grey brown, brown-red, purple brown, reddish grey sandstone and calcareous shale.

18. **Prince Edward Island Government Well No 3** Drilled: 1910

Stratigraphic and coal drilling test, churn drill.
At 1.6 km (1 mile) northeast of Kinross and 1.6 km (1 mile) east of Glencoe Station, Queens County.

Elevation: approximately 35 m (115 feet).
Total depth: 623.0 m (2,044 feet).
Log submitted by I.D. Ingall.

0-623.0 m (0-2,044 feet)	Pictou Group: P.E.I. redbeds, bright terra-cotta-red sandstone, calcareous shale, mudstone breccia, shale.

19. **Prince Edward Island Government Well No 4** Drilled: 1910

Stratigraphic and coal drilling test, churn drill.
At 2 km (1¼ mile) from Little Sands, Kings County.

Elevation: approximately 15 m (50 feet).
Total depth: 634.6 m (2,082 feet).
Log submitted by I.D. Ingall.

0-271.3 m (0-890 feet)	Pictou Group: P.E.I. redbeds, red conglomerate and sandstone, terra-cotta-red sandy shale and shale.
271.3-634.6 m (890-2,082 feet)	Pictou Group: P.E.I. redbeds, sandstone, shaly sandstone, sandy shale, and shale.

20. **Hudson's Bay - Fina Northumberland Strait F-25** Drilled: 1970

Test well - rotary rig on drilling barge.
Approximately 35 km (22 miles) east of Georgetown, Northumberland Strait.

Elevation: sea level.
Total depth: 3,010.2 m (9,876 feet).
Log submitted by Hudson's Bay Oil and Gas Co Ltd.

0-39.3 m (0-129 feet)	to ocean floor.		
39.3-365.8 m (129-1,200 feet)	Pre-Pictou strata: Canso Group (?) fine grained red and green siltstone.		
Interval	112.8-350.5 m (370-1,150 feet)	possibly early Namurian (Barss et al., 1979)	
365.8-2,042.2 m (1,200-6,700 feet)	Windsor Group: red siltstone, dolomite, limestone, anhydrite and halite interbeds.		
1,374.6-1,880.6 m (4,510-6,170 feet)	Windsor Group: salt.		
Interval	405.4-1255.8 m (1,330-4,120 feet)	late Visean	
Interval	2,023.9-2,026.9 m (6,640-6,650 feet)	Visean in age.	
2,042.2-2,950.5 m (6,700-9,680 feet)	Horton Group(?): red shale and sandstone; conglomerate towards base.		
Interval	2,580.1-2,898.6 m (8,465-9,510 feet)	two mafic volcanic horizons, each approximately 95 m (310 feet) thick, separated by conglomerate.	
2,950.5-3,010.2 m (9,680-9,876 feet)	Metamorphic basement/metasedimentary rocks.		

21. **Soquip et al. Naufrage No 1** Drilled: 1975

Test well, rotary rig.
Just west of the Village of Naufrage, along the north shore, approximately 64 km (40 miles) northeast of Charlottetown, Kings County.

Elevation: 22.3 m (73 feet).
Total depth: 3,105.3 m (10,188 feet).
Log submitted by Soquip et al.

0-655.3 m (0-2,150 feet)	Pictou Group: P.E.I. redbeds, mainly bright red sandstone, conglomerate and siltstone.	
655.3-2,926.1 m (2,150-9,600 feet)	Pictou Group: Transition sequence and "coal measures", grey and brownish-red sandstone, grey-greenish grey and brownish-red shale, coalified plant remains, calcareous sections.	
Interval	670.6-3,093.7 m (2,200-10,150 feet)	probably of Westphalian to Stephanian-Early Permian age (Soquip et al. Naufrage No 1, 1975).
2,926.1-3,105.3 m (9,600-10,188 feet)	Pre-Pictou strata (?) probably Cumberland or Riversdale.	
Interval	2,987.0-3,093.7 m (9,800-10,150 feet)	probably of Westphalian age (Soquip et al. Naufrage No 1, 1975).

22. **Hudson's Bay - Fina East Point E-49** Drilled: 1970

Test well, rotary rig on drilling barge.
Approximately 32 km (20 miles) northeast of East Point, Gulf of St Lawrence.

Elevation: sea level.
Total depth: 3,526.2m (11,569 feet).
Log submitted by Hudson's Bay Oil and Gas Co Ltd.

0-71.6 m (0-235 feet)	to ocean floor	
71.6-960.1 m (235-3,150 feet)	Pictou Group: P.E.I. redbeds, red sandstone, shale and siltstone, few conglomerate pebbles recorded.	
960.1-2,907.8 m (3,150-9,540 feet)		
Interval	1,051.6-2,856.0 m (3,450-9,370 feet)	ranges in age from Westphalian D(?) to Stephanian - Sakmarian (Early Permian) (Barss et al., 1979).
---------- disconformity ----------		
2,907.8-3,526.2 m (9,540-11,569 feet)	Pre-Pictou strata: Canso-Windsor Groups; mainly brown to grey shale, minor limestone, sandstone.	
Interval	2,907.8-3,307.1 m (9,540-10,850 feet)	ranges in age from late Visean to early Namurian (Barss et al., 1979).

GEOLOGICAL MAP OF
PRINCE EDWARD ISLAND

LEGEND

MESOZOIC

Middle Triassic

5	Tholeiitic Diabase

UPPER PALEOZOIC

Pictou Group ("Prince Edward Island redbeds"), subdivided:

Lower Permian

IV	**Megacyclic Sequence IV** Redbeds: conglomerate and sandstone; plant fossils absent. Basal conglomerates "mature" (quartz + quartzite 78-95%, rhyolite 0-14%, roundness 0.45-0.60); plant fossils not observed
III	**Megacyclic Sequence III** Redbeds: conglomerate, sandstone and siltstone; plant fossils apparently absent. Basal conglomerates "submature" (quartz + Lower Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52) in central and western parts of Island, "immature" in southeastern part of Island (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44); plant fossils not observed
IIIA	**Subcyclic Sequence IIIA** Redbeds: conglomerate and siltstone; plant fossils not observed. Basal conglomerate "immature" (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44)
II	**Megacyclic Sequence II** Redbeds: conglomerate, sandstone and siltstone; plant fossils and fern imprints locally present. Basal conglomerates "submature" (quartz + quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52); fossil plant stems locally common

Stephanian/ Upper Pennsylvanian

I	**Megacyclic Sequence I** Red and grey beds, sandstone and siltstone, minor conglomerate; transitional sequence – coal measures to redbeds; plant fossils and fern imprints locally very common
IA	**Subcyclic Sequence IA** Redbeds: coarse to fine sandstone and siltstone; fossil fern imprints very common

SYMBOLS

- *Coastal Outcrop*
- *Inland exposure*
- c *Conglomerate*
- *Shallow water well (conglomerate reported)*
- *Diamond drill hole*
- *Exploratory oil well*
- *Approximate geological contact (megacyclic sequence)*
- *Approximate geological contact (member sequence)*
- *Fault*
- *Anticline*
- *Syncline*
- *Bedding attitudes: horizontal, inclined*
- A B C *Conglomerate designation*
- F *Plant fossil locality*

GULF OF ST. LAWRENCE

North Point
Tignish
Cape Kildare
P.E.I. Well #5 TD 1670'
Miminegash
Miminegash Pond
Alberton
Cascumpec Bay
Campbellton
Foxley Bay
O'Leary
Cape Wolfe
Percival Bay
West Point
Subsurface extension of Bellevale Bay Fault
EGMONT BAY
Lennox Island
Hog Island
George Island
Tyne Valley
MALPEQUE BAY
Port Hill Well TD 4649'
Grand River
MacDougall Well TD 9081'
MacDougall 1A TD 2338'
Wellington
Miscouche
SUMMERSIDE
Water Well TD 1,100'
Wellington Stn Well #1 TD 9714'
Wellington Stn #2 TD 364'
Subsurface extension of Pettcodiac Fault
BEDEQUE BAY
Darnley Basin
Cape Tryon
Irishtown Well TD 13,477'
French River Well TD 200'
New London Bay
Orby Head
Cavendish
Green Gables Well TD 11,250'
North Rustico
Rustico Bay
Stanhope
Tracadie Bay
Cowhead Bay
Brackley Bay
Kensington
Hunter River
CHARLOTTETOWN
York River
Hillsborough River
Kelly Cross Well TD 1501'
Tyrone Well TD 13,670'
Elliot River
Governors Island Well TD 5970'
HILLSBOROUGH BAY

EOLOGICAL MAP OF
CE EDWARD ISLAND

LEGEND

subdivided:

e and sandstone; plant fossils absent. Basal conglomerates
4%, roundness 0.45-0.60); plant fossils not observed

e, sandstone and siltstone; plant fossils apparently absent.
er Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.35-
ature" in southeastern part of Island (quartz + quartzite
l fossils not observed

e and siltstone; plant fossils not observed. Basal conglom-
olite 0-8%, roundness 0.15-0.44)

, sandstone and siltstone; plant fossils and fern imprints locally
z + quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52);

dstone and siltstone, minor conglomerate; transitional sequence
mprints locally very common

e sandstone and siltstone; fossil fern imprints very common

SYMBOLS

- Coastal Outcrop
- Inland exposure
- c Conglomerate
- Shallow water well (conglomerate reported)
- Diamond drill hole
- Exploratory oil well
- Approximate geological contact (megacyclic sequence)
- Approximate geological contact (member sequence)
- Fault
- Anticline
- Syncline
- Bedding attitudes: horizontal, inclined
- Ⓐ Ⓑ Ⓒ Conglomerate designation
- F Plant fossil locality

Geology by H. W. van de Poll, 1977, 1980, in part modified after V. K. Prest, 1962, 1972, and L. Frankel, 1966.

0 2 4 6 8 10 MILES
0 2 4 6 8 10 12 14 16 KM
SCALE 1:250,000

ST. LAWRENCE

East Point
North Lake
Souris
Naufrage Well TD 10,188'
Rollo Bay
St. Peters Bay
Annandale
Broughton Bay
Boughton Island
CARDIGAN BAY
Georgetown
Panmure Island
St. Mary's Bay
Montague
Murray Head
Cape Bear
Murray River
Murray Harbour
Orby Head
Cape Tryon
Cavendish
North Rustico
Stanhope
New London Bay
Rustico Bay
French River Well TD 200'
Green Gables Well TD 11,250'
Mount Stewart
Kensington
Hunter River
CHARLOTTETOWN
Hillsborough River
York River
Crown Point Well TD 615'
HILLSBOROUGH BAY
Governors Island Well TD 5870'
Tyrone Well TD 13,670'
Kelly Cross Well TD 1501'
P.E.I. #3 TD 2044'
P.E.I. #2 TD 1885'
P.E.I. #1 TD 1910'
Earnscliffe Well TD 501'
Orwell Bay
Pownal Bay
Grand Point Anomaly
Trinity Harbour
Stanley Bridge
Bideford
Tracadie Bay
Covehead Bay
Brackley Bay
Hog Island
Lennox Island
Malpeque Bay
Egmont Bay
Bedeque Bay
Summerside
Miminegash
Tignish
Alberton
Port Hill
Souris
Elliott River
Lower Montague
Bridgetown
Montague River

SCINTILLOMETER ANOMALY MAP
PRINCE EDWARD ISLAND

LEGEND

MESOZOIC

Middle Triassic — 5 — Tholeiitic Diabase

UPPER PALEOZOIC

Pictou Group ("Prince Edward Island redbeds"), subdivided:

Lower Permian

- IV — **Megacyclic Sequence IV** Redbeds: conglomerate and sandstone; plant fossils absent. Basal conglomerates "mature" (quartz + quartzite 78-95%, rhyolite 0-14%, roundness 0.45-0.60); plant fossils not observed
- III — **Megacyclic Sequence III** Redbeds: conglomerate, sandstone and siltstone; plant fossils apparently absent. Basal conglomerates "submature" (quartz + Lower Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52) in central and western parts of Island, "immature" in southeastern part of Island (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44); plant fossils not observed
- IIIA — **Subcyclic Sequence IIIA** Redbeds: conglomerate and siltstone; plant fossils not observed. Basal conglomerate "immature" (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44)
- II — **Megacyclic Sequence II** Redbeds: conglomerate, sandstone and siltstone; plant fossils and fern imprints locally present. Basal conglomerates "submature" (quartz + quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52); fossil plant stems locally common

Stephanian/ Upper Pennsylvanian

- I — **Megacyclic Sequence I** Red and grey beds, sandstone and siltstone, minor conglomerate; transitional sequence – coal measures to redbeds; plant fossils and fern imprints locally very common
- IA — **Subcyclic Sequence IA** Redbeds: coarse to fine sandstone and siltstone; fossil fern imprints very common

SYMBOLS

- *Coastal Outcrop*
- *Inland exposure*
- c — *Conglomerate*
- *Approximate geological contact (megacyclic sequence)*
- *Approximate geological contact (member sequence)*
- *Fault*
- *Anticline*
- *Syncline*
- A B C — *Conglomerate designation*
- F — *Plant fossil locality*

Scintillometer Anomalies

- *2.0 - 3.0 x background*
- *3.0 - 4.0 x background*
- *4.0 - 5.0 x background*

GULF OF ST. LAWRENCE

North Point · Tignish · Cape Kildare · Miminegash · Alberton · Cascumpec Bay · Campbellton · O'Leary · Cape Wolfe · West Point · EGMONT BAY · Tyne Valley · Wellington · Miscouche · SUMMERSIDE · MALPEQUE BAY · George Island · Lennox Island · Hog Island · Foxley Bay · Percival Bay · Ground River · Thornley Basin · BEDEQUE BAY · Cape Tryon · New London Bay · Orby Head · Cavendish · North Rustico · Rustico Bay · Kensington · Hunter River · Stanhope · Brackley Bay · Trinity Head Bay · Tracadie Bay · CHARLOTTETOWN · York River · Hillsborough River · Elliott River · HILLSBOROUGH BAY

Subsurface extension of Bideford Bay Fault

Subsurface extension of Pennsdale Fault

LOMETER ANOMALY MAP
E EDWARD ISLAND

EGEND

bdivided:

and sandstone; plant fossils absent. Basal conglomerates
, roundness 0.45-0.60); plant fossils not observed

sandstone and siltstone; plant fossils apparently absent.
Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.35-
ure" in southeastern part of Island (quartz + quartzite
ossils not observed

and siltstone; plant fossils not observed. Basal conglom-
te 0-8%, roundness 0.15-0.44)

andstone and siltstone, plant fossils and fern imprints locally
+ quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52);

one and siltstone, minor conglomerate; transitional sequence
nts locally very common

sandstone and siltstone; fossil fern imprints very common

SYMBOLS

- *Coastal Outcrop*
- *Inland exposure*
- c *Conglomerate*
- *Approximate geological contact (megacyclic sequence)*
- *Approximate geological contact (member sequence)*
- *Fault*
- *Anticline*
- *Syncline*
- Ⓐ Ⓑ Ⓒ *Conglomerate designation*
- F *Plant fossil locality*

Scintillometer Anomalies

- ▪ *2.0 3.0 x background*
- ★ *3.0 4.0 x background*
- ● *4.0 5.0 x background*

0 2 4 6 8 10 MILES
0 2 4 6 8 10 12 14 16 KM
SCALE 1:250,000

Geology by H. W. van de Poll, 1977, 1980, in part modified after V. K. Prest, 1962, 1972, and L. Frankel, 1966.

ST. LAWRENCE

East Point
North Lake
Souris
Rollo Bay
St Peters Bay
Annandale
Boughton Bay
Boughton Island
CARDIGAN BAY
Georgetown
Panmure Island
Montague
St. Mary's Bay
Murray Head
Cape Bear
Murray Harbour
Murray River
Orby Head
Cape Tryon
Cavendish
New London Bay
North Rustico
Rustico Bay
Stanhope
Mount Stewart
Hunter River
Kensington
CHARLOTTETOWN
Hillsborough River
HILLSBOROUGH BAY
Orwell Bay
Pinwall Bay
Gaetz Point Anticline
Elliott River
Trout River
Salmar Syncline
Savage Har.

I II III IV IIIA

Lower Permian	III	**Megacyclic Sequence III** Redbeds: conglomerate, sandstone and siltstone; plant fossils apparently absent. Basal conglomerates "submature" (quartz + Lower Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52) in central and western parts of Island, "immature" in southeastern part of Island (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44); plant fossils not observed
	III^{A}	**Subcyclic Sequence IIIA** Redbeds: conglomerate and siltstone; plant fossils not observed. Basal conglomerate "immature" (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44)
Stephanian/ Upper Pennsylvanian	II	**Megacyclic Sequence II** Redbeds: conglomerate, sandstone and siltstone; plant fossils and fern imprints locally present. Basal conglomerates "submature" (quartz + quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52); fossil plant stems locally common
	I	**Megacyclic Sequence I** Red and grey beds, sandstone and siltstone, minor conglomerate; transitional sequence – coal measures to redbeds; plant fossils and fern imprints locally very common
	I^{A}	**Subcyclic Sequence IA** Redbeds: coarse to fine sandstone and siltstone; fossil fern imprints very common

- *Exploratory oil well*
- *Approximate geological contact (megacyclic sequence)*
- *Approximate geological contact (member sequence)*
- *Fault*
- *Anticline*
- *Syncline*
- *Bedding attitudes: horizontal, inclined*
- *Conglomerate designation*
- *Plant fossil locality*

GULF OF ST. LAWRENCE

NORTHUMBERLAND STRAIT

Cape Kildare
P.E.I. Well #5 TD 1670'
Miminegash
Miminegash Pond
Alberton
Cascumpec Bay
Campbellton
Foxley Bay
O'Leary
Cape Wolfe
Percival Bay
Subsurface extension of Belfast Bay Fault
EGMONT BAY
West Point
Lennox Island
Hog Island
George Island
Tyne Valley
MALPEQUE BAY
Port Hill Well TD 4649'
Grand River
MacDougall Well TD 9081'
MacDougall 1A TD 2338'
Wellington
Miscouche
Water Well TD 1,100'
SUMMERSIDE
Wellington Stn Well #1 TD 9714'
Wellington Stn #2 TD 364'
Subsurface extension of Pettcodiac Fault
BEDEQUE BAY
Cape Egmont
Seacow Head
Port Borden
Victoria
De Sable
Rice Point
St. Peters Island
Cape Tryon
Darnley Basin
Irishtown Well TD 13,477'
French River Well TD 200'
New London Bay
Orby Head
Cavendish
Green Gables Well TD 11,250'
North Rustico
Rustico Bay
Kensington
Hunter River
Stanhope
Covehead Bay
Brackley Bay
Tracadie Bay
CHARLOTTETOWN
York River
Hillsborough River
Kelly Cross Well TD 1501'
Tyrone Well TD 13,670'
Elliott River
Governors Island Well TD 5970'
Hillsborough Well TD 14,896'
HILLSBOROUGH BAY

Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.
" in southeastern part of Island (quartz + quartzite
fossils not observed

and siltstone; plant fossils not observed. Basal conglom-
ite 0-8%, roundness 0.15-0.44)

andstone and siltstone; plant fossils and fern imprints locally
tz + quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52);

dstone and siltstone, minor conglomerate; transitional sequence
imprints locally very common

ne sandstone and siltstone; fossil fern imprints very common

Approximate geological contact (member sequence)
Fault
Anticline
Syncline
Bedding attitudes: horizontal, inclined
Conglomerate designation
Plant fossil locality

S T. L A W R E N C E

S T R A I T

Cape Tryon
Orby Head
Cavendish
North Rustico
New London Bay
Green Gables Well TD 11,250'
French River Well TD 200'
Rustico Bay
Stanhope
Cowheat Bay
Brackley Bay
Tracadie Bay
Savage Har.
St. Peter's Bay
Naufrage Well TD 10,188'
Souris
Rollo Bay
Annandale
Boughton Bay
Boughton Island
CARDIGAN BAY
Brudenell
Georgetown
Montague River
Panmure Island
St. Mary's Bay
Montague
Kensington
Hunter River
CHARLOTTETOWN
York River
Hillsborough River
Crown Point Well TD 615'
Tyrone Well TD 13,670'
Kelly Cross Well TD 1501'
HILLSBOROUGH BAY
Governors Island Well TD 5970'
Hillsborough Well TD 14,806'
P.E.I. #1 TD 1910'
Firwood Bay
Green Point Anticline
P.E.I. #2 TD 1685'
Earnscliffe Well TD 501'
Orwell Bay
P.E.I. #3 TD 2044'
Rice Point
St. Peters Island
Victoria
De Sable
Port Borden
Prim Point
P.E.I. #4 TD 2082'
Wood Islands
Murray River
Murray Harbour
Murray Head
Cape Bear
Mount Stewart
N

Lower Permian	III	**Megacyclic Sequence III** Redbeds: conglomerate, sandstone and siltstone; plant fossils apparently absent. Basal conglomerates "submature" (quartz + Lower Permian quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52) in central and western parts of Island, "immature" in southeastern part of Island (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44); plant fossils not observed
	IIIA	**Subcyclic Sequence IIIA** Redbeds: conglomerate and siltstone; plant fossils not observed. Basal conglomerate "immature" (quartz + quartzite 50-78%, rhyolite 0-8%, roundness 0.15-0.44)
Stephanian Upper Pennsylvanian	II	**Megacyclic Sequence II** Redbeds: conglomerate, sandstone and siltstone; plant fossils and fern imprints locally present. Basal conglomerates "submature" (quartz + quartzite 51-69%, rhyolite 25-40%, roundness 0.35-0.52); fossil plant stems locally common
	I	**Megacyclic Sequence I** Red and grey beds, sandstone and siltstone, minor conglomerate; transitional sequence coal measures to redbeds; plant fossils and fern imprints locally very common
	IA	**Subcyclic Sequence IA** Redbeds: coarse to fine sandstone and siltstone; fossil fern imprints very common

Fault
Anticline
Syncline
Conglomerate designation
Plant fossil locality

Scintillometer Anomalies

- *2.0 3.0 x background*
- *3.0 4.0 x background*
- *4.0 5.0 x background*

GULF OF ST. LAWRENCE

NORTHUMBERLAND STRAIT

Cape Kildare
Miminegash
Miminegash Pond
Alberton
Campbellton
O'Leary
Cape Wolfe
West Point
EGMONT BAY
Cascumpec Bay
Foxley Bay
Percival Bay
Subsurface extension of Bellevue Bay Fault
Subsurface extension of Pembroke Fault
Wellington
Miscouche
SUMMERSIDE
Tyne Valley
Lennox Island
Hog Island
George Island
MALPEQUE BAY
Grand River
BEDEQUE BAY
Cape Egmont
Seacow Head
Port Borden
Victoria
De Sable
Rice Point
St. Peter's Island
Cape Tryon
Dunnley Basin
New London Bay
Orby Head
Cavendish
North Rustico
Rustico Bay
Stanhope
Brackley Bay
Covehead Bay
Trinity Harbour
Kensington
Hunter River
CHARLOTTETOWN
York River
Hillsborough River
Elliot River
Trout River
I
IA
II
III
IV

and L. Frankel, 1966.

...in southeastern part of Island (quartz + quartzite ...

...fossils not observed

...and siltstone; plant fossils not observed. Basal conglom... 0.8), roundness 0.15-0.44)

...sandstone and siltstone, plant fossils and fern imprints locally ... quartzite 51-60%, rhyolite 25-40%, roundness 0.35-0.52)

...stone and siltstone, minor conglomerate, transitional sequence ...imprints locally very common

...sandstone and siltstone; fossil fern imprints very common

Syncline

Conglomerate designation

Plant fossil locality

Scintillometer Anomalies

2.0 - 3.0 × background

3.0 - 4.0 × background

4.0 - 5.0 × background

S T. L A W R E N C E

S T R A I T

Cape Tryon

Orby Head

Cavendish

New London Bay

North Rustico

Rustico Bay

Stanhope

Brackley Bay

Covehead Bay

Tracadie Bay

Savage Har.

Mount Stewart

St. Peter's Bay

Souris

Rollo Bay

Annandale

Boughton Bay

Boughton Island

CARDIGAN BAY

Georgetown

Brudenell River

Montague River

Panmure Island

St. Mary's Bay

Montague

Kensington

Hunter River

CHARLOTTETOWN

York River

Hillsborough River

HILLSBOROUGH BAY

Pownal Bay

Orwell Bay

Gallas Point Anticline

Prim Point

Victoria

De Sable

Port Borden

St. Peter's Island

Rice Point

Murray River

Murray Harbour

Kilmuir Syncline

Murray Head

Cape Bear

Wood Islands

N

I

II

III

IV

46°

63°